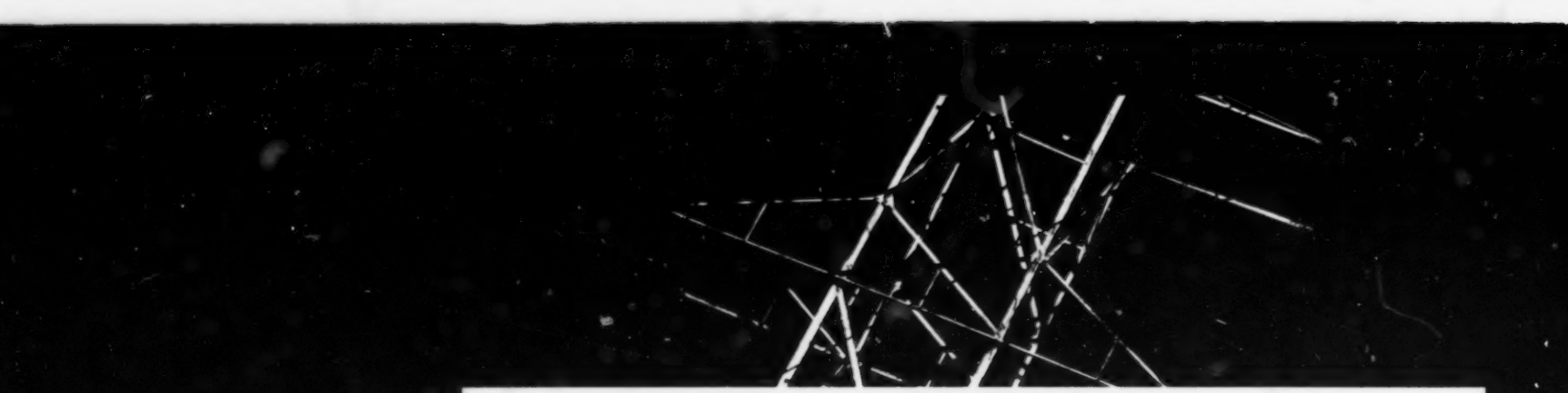

BC Hydro Conservation Potential Review 2002

Industrial Sector Report (Base Year: Fiscal 2000/01)

Electricity Conservation Potential in BC Hydro's Service Area

May 2003

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  Prepared by Polestar Communications Inc.
- **BC Hydro Conservation Potential Review 2002, Residential Sector Report.**
  Prepared by Marbek Resource Consultants and The Sheltair Group Inc.
- **BC Hydro Conservation Potential Review 2002, Commercial Sector Report.**
  Prepared by Marbek Resource Consultants
- **BC Hydro Conservation Potential Review 2002, Industrial Sector Report.**
  Prepared by Marbek Resource Consultants and Willis Energy Services Ltd.

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BC Hydro
Conservation Potential Review 2002

Industrial Sector Report
(Base Year: Fiscal 2000/01)

Submitted to:
BC Hydro

Prepared by:
Marbek Resource Consultants
and
Willis Energy Services

July 2003

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Completion of the Conservation Potential Review 2002 on an accelerated time table is due in no small part to the consistent input from many BC Hydro staff members, as well as the hard work of the consultants engaged by BC Hydro.

Conservation Potential Review Core Group

The heaviest load fell on the Conservation Potential Review Core Group, which oversaw the management of the effort. The Group consisted of the following members:

- Murray Bond—Quality Assurance Implementation, Power Smart Quality Assurance
- Dorell Carlson—Senior Resource Planning Specialist, Electricity Management
- Derek Henriques—Manager, Power Smart Quality Assurance & Evaluation
- Dennis Nelson—Manager, Business Systems Group
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Other BC Hydro Staff

Many others reviewed draft reports and participated in periodic meetings and conference calls. These individuals included the following BC Hydro staff (all are from Power Smart, unless otherwise identified):

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External Review Panel

A number of organizations in B.C. also agreed to serve on an External Review Panel. They reviewed and commented on draft reports. However, their participation on the Panel should not be construed as indicating agreement with, or endorsement of, any of the CPR 2002 reports. Members of the Panel include:

- Canadian Home Builders' Association of B.C.
- B.C Public Interest Advocacy Centre—Michael Doherty & Dick Gathercole
- Building Owners' and Managers' Association—Paul LaBranche
- Joint Industry Electric Steering Committee—Lorne Grasley, Dal Scott, Lisa Doig and Dan Potts
- Kootenay–Okanagan Electric Consumers' Association—Fred Marsh
- Pembina Institute for Appropriate Development—Roger Peters
- Sierra Club of B.C.—Tom Hackney, Bo Martin, and Michael Mascall
- David Suzuki Foundation—Dermot Foley
- Union of B.C. Indian Chiefs—David Hunt and Don Bain.

Consultants

The Conservation Potential Review 2002 was undertaken by a team of consultants headed by Marbek Resource Consultants, Ltd. of Ottawa, Ontario. The Industrial Sector team included:
Paul Willis and Penny Cochrane—Willis Energy Services Ltd.
Timo Mackinen—BC Research Inc.
Charles Nishi—CWA Engineers Inc.
John Nyboer—J. & C. Nyboer
Alex Fleming—Demand Side Energy Consultants Inc.

The CPR effort was coordinated by Nancy J. Cooley of Nancy J. Cooley & Associates: Embracing Change Creatively, Inc. of Victoria. B.C., who provided day-to-day management.

EXECUTIVE SUMMARY

❑ Background and Objectives

In 1991, BC Hydro launched the first collaborative study to estimate the potential for energy conservation in a Canadian utility. The result was an in-depth analysis of where, how and at what cost electricity consumption in British Columbia (B.C.) could be reduced through electrical efficiency and behavioural changes. A decade later, continued provincial load growth as well as increasing environmental concerns had led to renewed interest in electrical efficiency and, in light of that interest, a decision was made to update the original Conservation Potential Review (CPR) in support of a new set of Power Smart initiatives. This study has been designed with a very tight time frame in order to meet Power Smart planning requirements.

The study had the following objectives:

- To provide BC Hydro's Power Smart program planners with an updated assessment of the remaining hard-wired electrical efficiency potential[1] in B.C. as a basis for designing new initiatives.
- To estimate the potential contribution of possible Power Smart efficiency programs to the reduction of BC Hydro's peak capacity requirements.
- To identify additional technologies that could become available to provide further savings over the study period.

❑ Scope

It was originally envisioned that the entire scope of this study would directly follow the structure and approach of the original CPR. However, the context has altered significantly in the ten years since the original CPR: electricity markets throughout North America have changed radically as a result of moves towards deregulation and privatization; better energy-use data for buildings, equipment and industrial processes are available; computer modelling tools for simulating energy use are more sophisticated; and, perhaps most importantly, North American utilities have an additional 10 years' experience in the design, promotion and implementation of DSM programs to draw upon. Consequently, with limited resources available, it was decided to focus on those areas that would best assist BC Hydro's Power Smart planners with the planning and design of new Power Smart initiatives. The intent was also to ensure that the results of this study have a good "shelf life" for Power Smart program and resource planning purposes.

Sector Coverage: This study addresses three sectors: Industrial, which is covered in the present report and, Residential and Commercial/Institutional, which are addressed in separate documents.

[1] The focus was on "hard-wired" electrical efficiency measures; these types of measures are not dependant on repeated customer behaviour to be effective. From a utility's perspective they provide reliable and persistent savings.

Geographical Coverage: The study results are presented for the total BC Hydro service region, excluding the (former) West Kootenay Power service region. This study also provides the results for three regions (Lower Mainland, Vancouver Island and the Interior).[2]

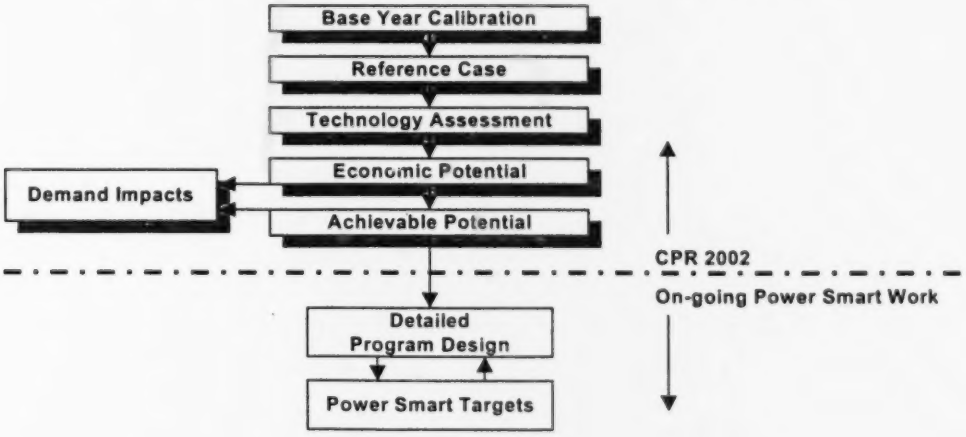
Study Period: This study covers a 15-year period. The base year is the fiscal year (FY) 2000/01, with milestone years at 5-year increments: 2005/06, 2010/11 and 2015/16. The base year of FY 2000/01[3] was selected as this was the most recent 12-month period for which complete customer data were available.

Technologies: This study addresses electrical efficiency technologies or measures that are expected to be commercially viable by the year 2005. Other technologies that control or shift electrical demand or that represent alternative sources of supply are outside of the scope of this study. The use of direct load control technologies or thermal storage provide examples of the former group of excluded technologies while the use of natural gas fired engines to drive compressors and pumps provide examples of the latter group.

❑ Approach

The analysis of the Industrial Sector employed ISTUM to simulate the electricity and other energy demands of the major industrial subsectors (pulp and paper, wood products, chemical products, coal mining, metal mining and petroleum refining) in BC Hydro's service area. The ISTUM model is an end-use computer model of the Industrial Sector. This model was used to analyze the industrial sector in BC Hydro's first Conservation Potential Review, completed in 1994. The Energy and Materials Research Group at Simon Fraser University has since used the model for a variety of studies. Since the model is used on an ongoing basis, this study has benefited from improvements made to ISTUM over the past decade.

Exhibit E1: Study Approach—Major Analytical Steps



[2] ***Lower Mainland*** includes the Lower Mainland of B.C., the Fraser Valley as far east as Hope, the Sunshine Coast and Powell River. ***Vancouver Island*** includes all of Vancouver Island plus those Gulf Islands that get their electricity supply from Vancouver Island. ***Interior*** includes the remainder of BC Hydro's service area. Areas that are not integrated into BC Hydro's grid are not included.

[3] BC Hydro's fiscal year runs from April 1 to March 31.

The major steps involved in the analysis are shown in Exhibit E1 and are discussed in the following paragraphs. As illustrated, the results of this CPR study, and in particular the estimation of Achievable Potential, support ongoing Power Smart work; however, it should be emphasized that the estimation of Achievable Potential is not synonymous with either the setting of specific Power Smart targets or with program design.

❑ Major Analytic Steps and Definitions

This study employs numerous terms that are unique to analyses such as this one; below is a brief description of some of the most important terms. (Others are provided in the Glossary.)

Base Year Calibration — The Base Year is the starting point for the analysis. It provides a detailed description of "where" and "how" electricity is currently used in the industrial sector. Energy use simulations were undertaken for each of the industrial subsectors and calibrated to actual BC Hydro customer billing data.

Reference Case (includes Natural Conservation) — The Reference Case estimates the expected level of electricity consumption that would occur over the study period in the absence of new (post 2000/01) Power Smart initiatives. It provides the point of comparison for the subsequent calculation of "economic" and "achievable" electricity savings potentials. Creation of the Reference Case required the development of detailed forecasts of future levels of production activity in each subsector as well as an estimation of "natural" changes affecting electricity consumption over the study period.

Technology Assessment — Electricity efficiency upgrade options were identified that met the criteria, as outlined above in the study's scope. Technology cost and performance data were compiled relative to the base line technology and the Cost of Conserved Energy (CCE) was calculated for each upgrade option. The CCE is the annualized incremental capital and O&M cost of the upgrade measure divided by the annual energy savings achieved.

Economic Potential Forecast — The Economic Potential Forecast is the level of electricity consumption that would occur if all equipment and production processes were upgraded to the level that is cost-effective, from BC Hydro's perspective using life-cycle costing, against the long-run avoided cost of electricity in the BC Hydro service region, which in this study was set at $0.06/kWh. All the electrical efficiency upgrades included in the technology assessment that had a CCE[4] equal to, or less than, the avoided cost of new electricity supply ($0.06/kWh) were incorporated into the Economic Potential Forecast.

[4] The CCE is defined in Section 4.

Achievable Potential

The Achievable Potential is the proportion of the savings identified in the Economic Potential Forecast that could realistically be achieved within the study period. Achievable Potential recognizes that it is difficult to induce customers to purchase and install all the energy-efficient technologies that meet the criteria defined by the Economic Potential Forecast. For the industrial sector, development of the Achievable potential also recognizes that it is not practical to install efficient equipment in facilities with uncertain futures. The results are presented as a range, defined as most likely and upper.[5]

Estimates provided were developed in collaboration with Power Smart program personnel; they are based on a combination of empirical results from earlier Power Smart initiatives, results in other jurisdictions and a qualitative assessment of current market and customer receptivity to investments in energy efficiency. The range of estimates also recognizes that in addition to factors within BC Hydro's control (e.g., program design), factors external to the utility (e.g., state of economy, Kyoto implications etc.) can significantly influence the Achievable Potential.

❑ Results and Findings

A summary of the levels of annual electricity consumption contained in each of the preceding forecasts, by milestone year, is presented in Exhibits E2 and E3, and discussed briefly in the paragraphs below.

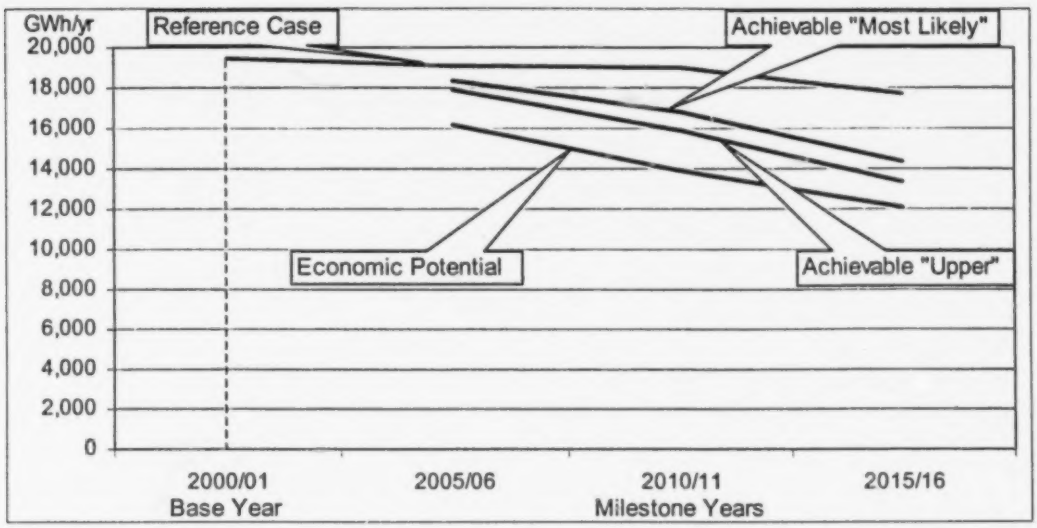
Exhibit E2: Summary of ISTUM Forecast Results—Annual Electricity Consumption in the Industrial Sector, (GWh/yr.)*

Annual Electricity Consumption (GWh/yr.) Industrial Sector						Potential Annual Savings (GWh/yr.)		
Milestone Year	Base Year	Reference Case	Economic	Achievable		Economic	Achievable	
				Most Likely	Upper		Most Likely	Upper
2000/01	19,753	19,753						
2005/06		19,162	16,250	18,415	17,973	2,912	747	1,189
2010/11		19,045	13,943	16,894	15,987	5,102	2,151	3,058
2015/16		17,821	12,156	14,447	13,483	5,665	3,374	4,338

*Results are measured at the customer's point of use and do not include line losses.

[5] Definitions of the Achievable scenarios are provided in Section 6.2.

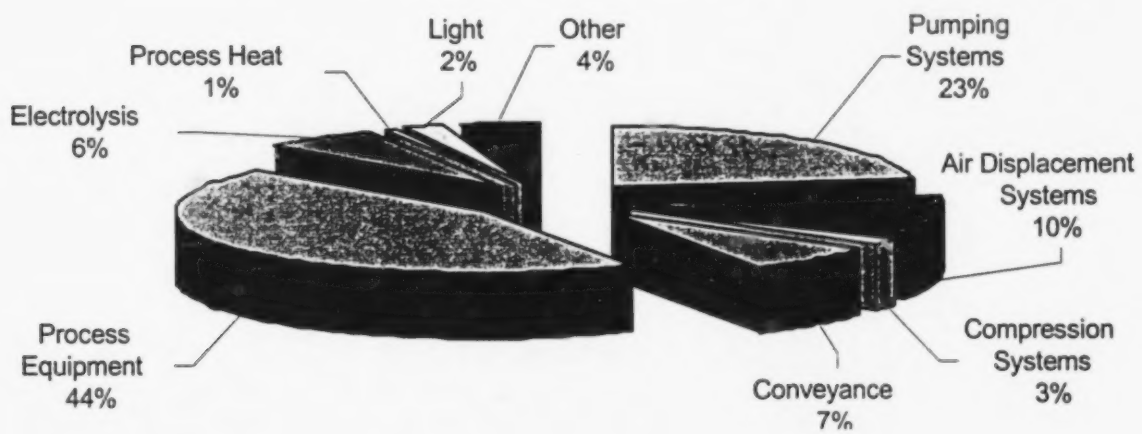
Exhibit E3: Graphic of ISTUM Forecast Results—Annual Electricity Consumption in the Industrial Sector, (GWh/yr.)



Base Year Energy Use and Calibration

In the base year of 2000/01, BC Hydro's industrial sector consumed approximately 19,753 GWh/yr. Exhibit E4 shows that process equipment[6] is the major end use and accounts for about 44% of the total industrial sector electricity use. Pumping is the second largest end use, accounting for about 23% of total electricity use, followed by air displacement systems (10%).

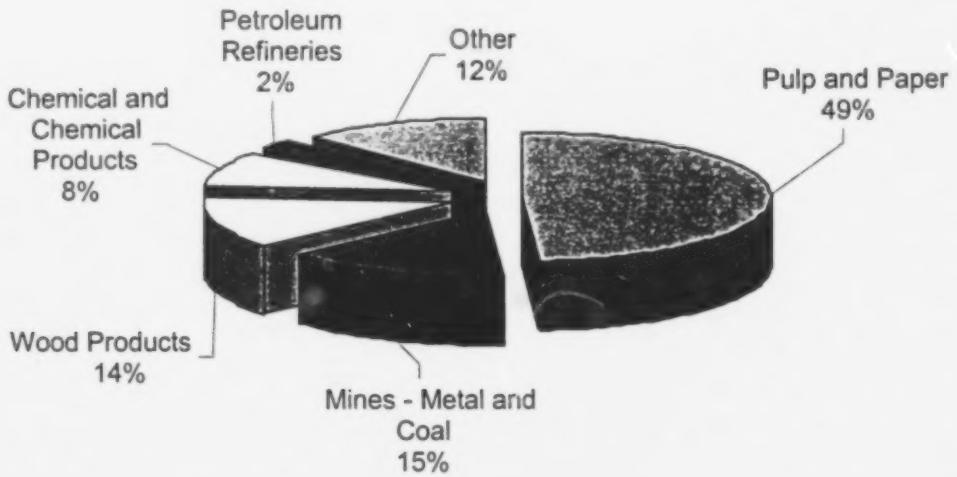
Exhibit E4
Industrial Sector
Base Year Electricity Use By End Use



[6] Examples of process equipment include: metal ore grinding machines or wood-chip pulp refiners.

Exhibit E5 shows the distribution of base year electricity consumption by industrial sub sector. As illustrated, pulp and paper (49%) accounts for the largest share of electricity use in this sector, followed by metal and coal mining (15%) and wood products (14%). The "Other" industrial sub sector consists of industrial facilities not included in the major industrial subsectors; it accounts for 12% of the industrial base year electricity use.

Exhibit E5: Industrial Sector Base Year Electricity Use By Subsector



Reference Case

In the absence of new Power Smart initiatives, the study estimated that industrial electricity consumption would be 19,162 GWh/yr. in 2005/06, 19,045 GWh/yr. in 2010/11 and 17,821 GWh/yr. in 2015/16. This represents a negative average annual growth rate of -0.56% over the study period. It differs from the BC Hydro reference forecast that grows at an average annual growth rate of 0.38%. It is acknowledged that the growth of industrial electricity consumption in British Columbia has been declining, reflecting British Columbia's general shift from a resource-based to a service-based economy. The decline in this Reference Case also reflects modelling assumptions including: the anticipated mix and quantity of future industrial products and sub-products; future technological and other changes that impact the electrical intensity of industrial production; and, the level of self-generation adopted by industry.

Economic Potential Forecast

Under the conditions of the Economic Potential Forecast, the study estimated that electricity consumption in the Industrial Sector would decline to 12,155 GWh/yr. by fiscal year 2015/16. Annual savings relative to the Reference Case are 5,665 GWh/yr., or about 32%. The Economic Potential annual savings in the remaining milestone years are 5,102 GWh/yr. in 2010/11 and 2,912 GWh/yr. in 2005/06. The most significant savings are from pumping and mechanical pulping systems.

Achievable Potential

The electricity savings opportunities identified in the Economic Potential Forecast were "bundled", by end use, into a set of "Actions" reflecting a way in which initiatives may be undertaken. A brief profile was developed for each of the identified Actions. The Action Profiles provided a high-level logic framework that guided participant discussions in a full-day workshop as well as follow up meetings involving the consultant team and Power Smart personnel. The results are presented in Exhibit E6 by Action and by milestone year.

Consistent with the results in the Economic Potential Forecast, the most significant Achievable Savings opportunities were in the Actions that addressed pumping and mechanical pulping systems.

Exhibit E6: Summary of Achievable Savings, by Action and Milestone Year*

Action	Annual Electricity Savings by Milestone Year, (GWh/yr.)					
	2005/06		2010/11		2015/16	
	Most Likely	*Upper*	*Most Likely*	*Upper*	*Most Likely*	*Upper*
I1—Pump Improvement	110	217	564	998	905	1,415
I2—Air Displacement Improvement	24	37	69	110	114	171
I3—Compressed Air Improvement	29	42	91	143	123	164
I4—Conveyance or Material Handling Improvement	19	38	71	113	100	143
I5—Refrigeration and Cooling Improvement	2	4	10	16	16	21
I6—Electric Motor Efficiency (not reported separately because motor efficiency improvements are included as part of the "system" efficiency improvements contained in Actions I1 through I5)						
I7—Industrial Lighting and Controls Improvement	24	48	113	186	163	236
I8—Mechanical Pulping Improvement	274	274	548	548	1,095	1,095
I9—Process Improvement	33	65	187	304	247	382
I10—Steam Cycle Optimization	218	437	428	524	504	542
I11—Industrial Indoor Air Quality	14	28	69	117	107	169
Total	747	1,189	2,151	3,058	3,374	4,338

*Results are measured at the customer's point of use and do not include line losses.

Demand Impacts of Energy Efficiency Measures

This study provided the first attempt by BC Hydro to estimate the demand impacts associated with the energy efficiency measures incorporated in each of the preceding forecasts. This study did not focus *per se* on demand reduction, and the technology and load control strategies that would reduce peak capacity requirements lie beyond the scope of the present work. However, as illustrated in Exhibit E7, electricity savings contained in each of the forecasts have significant on-peak demand implications.

Relative to the Reference Case, on-peak demand savings in the Economic Potential Forecast are 380 MW in FY 2005/06, rising to 666 MW and 739 MW in FYs 2010/11 and 2015/16, respectively. Achievable Potential on-peak demand savings in FY 2005/06 range from 97 MW (most likely) to 154 MW (upper), depending on scenario. By FY 2015/16 Achievable Potential

on-peak demand savings range from 436 MW (most likely) to 559 MW (upper), again depending on scenario.

Exhibit E7: On-Peak Demand Savings for Total BC Hydro Service Area in the Industrial Sector

Average On-peak Demand (MW)						Potential On-peak Demand Savings (MW)		
Milestone Year	Base Year	Reference Case	Economic	Achievable		Economic	Achievable	
				Most Likely	*Upper*		*Most Likely*	*Upper*
2000/01	2,542	2,542						
2005/06		2,503	2,123	2,406	2,349	380	97	154
2010/11		2,488	1,823	2,211	2,095	666	277	394
2015/16		2,331	1,591	1,895	1,771	739	436	559

* Includes line losses of 3% for transmission-level customers and 7% for distribution-level customers.

❑ Summary of Findings

The study findings confirm the existence of significant potential cost-effective electrical efficiency improvements in B.C.'s industrial sector. In the most likely and upper achievable scenarios those energy efficiency improvements would provide between 3,374 and 4,338 GWh/yr., respectively, of electricity savings by FY 2015/16 as well as on-peak demand savings of approximately 436 to 559 MW.

The three areas offering the most significant electricity saving opportunities are mechanical pulping enhancements, pump system improvements and steam cycle optimization (i.e., greater use of steam turbines to generate electricity at mill sites). These three areas account for 74% of the most likely achievable savings and all involve the pulp and paper sector. It is important to note that realizing these potential savings would require a significant amount of specialized engineering work and a significant level of capital investment. The study notes that the current market conditions provide a unique opportunity for BC Hydro to work with the pulp and paper subsector to improve its efficiency and competitiveness and, at the same time, to significantly reduce the amount of electricity used by this subsector.

Note: As in any study of this type, the results presented in this report are based on a number of important assumptions. Assumptions such as those related to the current penetration of efficient technologies and the rate of future growth in the stock of process equipment are particularly influential. Wherever possible, the assumptions used in this study are consistent with those used by BC Hydro. However, the reader is referred to a number of caveats throughout the main text of the report.

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1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

In 1991, BC Hydro launched the first collaborative process to estimate the potential for electricity conservation in a Canadian utility's service territory. A collaborative committee of electricity stakeholders oversaw the research, and the report presented an in-depth analysis of where, how, and at what cost electricity demand in British Columbia (B.C.) could be reduced through technology and behavioural changes.

A decade later, new pressures and structures in the industry are leading to renewed interest in conservation and load management. Increasing peak demands are encouraging consideration of demand-side management (DSM) as a means to defer transmission and generation investment in certain areas. At the same time, BC Hydro's natural-gas-based generation plan identifies risks related to increased greenhouse gas emissions, risks that electrical efficiency can mitigate. There is also renewed interest in neighbouring jurisdictions in conservation as a means to mitigate the risk of price spikes and shortages in competitive markets. Since the original Conservation Potential Review (CPR), the performance efficiency of major electricity-using technologies has continued to improve, new products have become available in the market, and additional technologies, based largely on advances in Information Technology (IT) and materials science, are under development and will offer further potential for electrical efficiency improvement.

Given the above conditions, BC Hydro initiated the current study with the following objectives:

- To provide BC Hydro's Power Smart program planners with an updated assessment of the remaining hard-wired electricity efficiency potential[7] within B.C., an assessment that will assist them in the design and implementation of a new set of Power Smart initiatives.
- To estimate the potential contribution of possible Power Smart efficiency programs to the reduction of BC Hydro's peak demand requirements.
- To identify additional technologies that could become available to provide further savings over the study period.

1.2 STUDY SCOPE

It was originally envisioned that the entire scope of this study would directly follow the structure and approach of the original CPR. However, the context has altered significantly in the 10 years since the original CPR: electricity markets throughout North America have changed radically as a result of moves towards deregulation and privatization; better energy-use data for buildings, equipment and industrial processes are available; computer modelling tools for simulating energy use are more sophisticated; and, perhaps most importantly, North American utilities have an additional 10 years' experience in the design, promotion and implementation of DSM programs to draw upon. Consequently, with limited resources available, it was decided to focus

[7] The focus was on "hard-wired" electrical efficiency measures; these types of measures are not dependant on repeated customer behaviour to be effective. From a utility's perspective they provide reliable and persistent savings.

on those areas that would best assist BC Hydro's Power Smart program planners with the design of new Power Smart initiatives. The intent was also to ensure that the results of this study have a good "shelf life" for Power Smart program and resource planning purposes. The most significant changes to the original CPR scope that were introduced in this study are as follows:

- **Focus is on economic potential.** The original CPR included estimates of unconstrained technical and social potential[8] for electricity savings. While these potentials provided useful reference points at the time, the experience of the last 10 years has emphasized the importance of the economic potential[9] as the basis for utility program planning.

  The estimated potentials from the original CPR were intended to establish what the outside limits of conservation might be if one could get 100% of all the technological changes available and projected at the time and if one could get all customers to behave in the most electricity conserving manner. When BC Hydro decided to update its estimates, it was more interested in how much of the remaining potential could be realistically achieved through renewed investment in DSM rather than what could be achieved through customers changing their behaviour. Consequently, this CPR focuses on economic potential and primarily on so called "hard-wired" options (those that are little or not at all affected by customer behaviour). The resulting potential estimates should, therefore, be read as a reasonable estimate of what BC Hydro could target with new Power Smart programs. Unlike the original CPR estimates, it cannot be read as an estimate of what the potential pool of conserved electric energy could be. Clearly, the latter is much larger than this CPR would indicate, since it would contain the effects of: changes in customer attitude and behaviour; changes in electricity rate structures; and changes in provincial and/or federal government policies and programs with respect to electricity.

- **Electricity savings are calculated relative to a Reference Case that includes natural conservation.** The original CPR calculated energy savings on the basis of a frozen efficiency forecast. However, this frozen efficiency forecast is not as relevant today, as electrical efficiency improvements have gained a momentum of their own and continue to be promoted by a variety of public- and private-sector proponents.

- **The demand impacts of the electrical efficiency measures are estimated.** Demand was not addressed in the original CPR; however, demand constraints have become a more important concern to BC Hydro than at the time of the original CPR. Consequently, this CPR includes an estimate of the demand reductions that would occur as a result of the electricity efficiency savings contained in the study.

(Note: specific load control or load-shifting measures are not included in the study scope.)

[8] The social potential that was included in the original CPR included attitude and behavioural changes such as turning off lights.

[9] The original CPR also attempted to quantify *all* technologies that were expected to become "economic" by the end of the study period. The current CPR set the first milestone year of 2005 as the economic cut-off date for quantitative inclusion of technologies in the economic potential forecast. This study does identify additional technologies that may become economic between 2005 and the end of the study period, but does not attempt to quantify their potential savings contribution.

With the exception of the above changes, the scope of this CPR remains largely unchanged from the 1991 study. More specifically:

- **Sector Coverage:** This study addresses the same three sectors: Industrial, which is covered in the present report and, Residential and Commercial/Institutional, which are addressed in separate documents.

- **Geographical Coverage**: The study results are presented for the total BC Hydro service area but exclude, as in the original CPR, the (former) West Kootenay Power service region. In contrast to the original CPR, this study also provides the results for three regions (Lower Mainland, Vancouver Island and the Interior).[10]

- **Study Period**: This study also covers a 15-year period. The base year is the fiscal year (FY) 2000/01, with milestone years at 5-year increments: 2005/06, 2010/11 and 2015/16. The base year of fiscal year 2000/01 was selected as this was the most recent 12-month period for which complete customer data were available.

- **Technologies:** This study addresses all electrical efficiency technologies or measures that are expected to be commercially viable by the year 2005. A summary of the technologies included in this study is provided in Exhibit 1.1.

Exhibit 1.1: Industrial Sector Technologies Included in Study

End Use	Efficient Technologies	Core Analysis	Emerging Technologies (*see* Section 8)
Pumping	High-efficiency pumps	X	
	Low-friction piping networks	X	
	Efficient drive systems	X	
	Pump system efficiency	X	
	Improved control (includes Adjustable Speed Drives)	X	
Air Displacement	High-efficiency fans	X	
	Low-friction ducts	X	
	Improved control (included Adjustable Speed Drives)	X	
Compression	Efficient compressors	X	
	Improved control (includes Adjustable Speed Drives and Increased Storage)	X	
	Reduced leaks	X	
	Efficient end use (efficient nozzles)	X	
	Efficient system with storage	X	
Conveyance	Conversion of pneumatic systems to mechanical systems	X	
	Low-friction mechanical systems (belts)	X	
	Direct couple drive	X	
	Tooth belt drive	X	
	Adjustable Speed Drives	X	

[10] ***Lower Mainland*** includes the Lower Mainland of B.C., the Fraser Valley as far east as Hope, the Sunshine Coast and Powell River. ***Vancouver Island*** includes all of Vancouver Island plus those Gulf Islands that get their electricity supply from Vancouver Island. ***Interior*** includes the remainder of BC Hydro's service area. Areas that are not integrated into BC Hydro's grid are not included.

Exhibit 1.1 (continued)

End Use	Efficient Technologies	Core Analysis	Emerging Technologies (*see* Section 8)
Refrigeration	Efficient compressors	X	
	Improved control	X	
	Increased insulation	X	
	Carbon dioxide refrigeration		X
	Thermo-acoustic refrigeration		X
	Magnetic refrigeration		X
	Linear compressions		X
Lighting	Fluorescent to high-pressure sodium or metal-halide	X	
	T12s to T8s	X	
	Improved control	X	
	High-wattage Compact Fluorescent Lights	X	
	Pulse-start metal-halide	X	
	Two-photon Lamp		X
Motors	National Electrical Manufacturers Association Premium motors	X	
	Advanced motors		X
	Amorphous motors		X
	Super-conducting motors		X
Debarking/ Chipping	Mechanical debarking versus hydraulic	X	
	Improved control on chipping	X	
Hydraulic Systems	Improved control	X	
Mechanical Pulping	Tertiary refining	X	
	High-speed refining	X	
	Improved control	X	
	On-line pulp analysis[11]	X	X
	Wood residue firing	X	
	Steam cycle optimization	X	
	Biological treatment of wood chips		X
	Advanced refiners		X
Mechanical Mixing	Aerofoil mixers	X	
Chemical Pulping	High consistency pumping	X	
	Continuous versus batch digestors	X	
	Steam cycle optimization	X	
	Black liquor gasification		X
	On-line pulp analysis[12]	X	X
	Tertiary effluent treatment	X	
	Wood residue firing	X	
	Medium consistency pumping		X
Pulp Bleaching	Ozone bleaching	X	
	Oxygen delignification	X	
	Polyoxometalate bleaching	X	
Paper Production	On-machine ultrasonic sensors for paper stiffness	X	
	Microwave drying		X
	Impulse drying		X

[11] On-line pulp analysis is included in both categories. This recognizes that techniques are currently commercially available and that new on-line technologies are under development.
[12] ibid

Exhibit 1.1 (continued)

End Use	Efficient Technologies	Core Analysis	Emerging Technologies (*see* Section 8)
Lumber Drying	Improved kiln control (includes ASDs)	X	
	Acoustic humidity sensors		X
	Wood residue firing	X	
	Radio frequency (RF) drying		X
Ore Crushing and Milling, Coal Mining	High-efficiency crushing	X	
	Improved control	X	
	Coal washing	X	
Water and Wastewater Treatment	Ultraviolet treatment	X	
	Membrane filtration	X	
	Enhanced aeration		X
	Electro de-ionization		X

As in the original CPR, other technologies that control or shift electrical demand or represent alternative sources of energy supply are outside of the scope of this study. The use of pulp storage and sophisticated peak shaving control equipment provide examples of the former group of excluded technologies while using natural-gas-fired engines to drive large compressors or pumps are examples of the latter.

Exhibit 1.1 also shows whether selected technologies are addressed in the "core" analysis or if they are considered as an emerging technology. The "core" technologies are incorporated in the main analysis. The technologies noted in the "emerging" column of Exhibit 1.1 have not yet reached the point of full commercialization; nonetheless, it is recognized that they could become commercially available in the study period. These latter technologies are addressed separately in Section 8 and their potential contribution to further energy savings over the study period is briefly noted.

1.3 DEFINITIONS

This study employs numerous terms that are unique to analyses such as this one and consequently it is important to ensure that all readers have a clear understanding of what each term means when applied to this study. Below is a brief description of some of the most important terms. The reader is also referred to the Glossary of Terms, (*see* Section 11 of this report). Key terms include:

Base Year Calibration The Base Year is the starting point for the analysis. It provides a detailed description of "where" and "how" electricity is currently used in the industrial sector. Electricity use simulations were undertaken for each of the industrial subsectors and calibrated to actual BC Hydro customer billing data.

Reference Case (includes Natural Conservation) The Reference Case estimates the expected level of electricity consumption that would occur over the study period in the absence of new (post 2000/01) Power Smart initiatives. It provides the point

of comparison for the subsequent calculation of "economic" and "achievable" electricity savings potentials. Creation of the Reference Case required the development of detailed forecasts of future levels of production activity in each subsector as well as an estimation of "natural" changes affecting electricity consumption over the study period.

Technology Assessment

Energy efficiency upgrade options were identified that met the criteria, as outlined above in the study's scope. Technology cost and performance data were compiled relative to the base line technology and the Cost of Conserved Energy (CCE) was calculated for each upgrade option. The CCE is the annualized incremental capital and O&M cost of the upgrade measure divided by the annual energy savings achieved.

Economic Potential Forecast

The Economic Potential Forecast is the level of electricity consumption that would occur if all equipment and production processes were upgraded to the level that is cost-effective against the long-run avoided cost of electricity in the BC Hydro service region, which in this study was set at $0.06/kWh. All the electrical efficiency upgrades included in the technology assessment that had a CCE equal to, or less than, the avoided cost of new electricity supply ($0.06/kWh) were incorporated into the Economic Potential Forecast.

Achievable Potential

The Achievable Potential is the proportion of the electricity savings identified in the Economic Potential Forecast that could realistically be achieved within the study period. Achievable Potential recognizes that it is practically difficult to induce customers to purchase and install all the efficiency technologies that meet the criteria defined by the Economic Potential Forecast. The results are presented as a range, defined as most likely and upper.

Estimates provided were developed in collaboration with Power Smart program personnel; they are based on a combination of empirical results from earlier Power Smart initiatives, results in other jurisdictions and a qualitative assessment of current market and customer receptivity to investments in electrical efficiency. The range of estimates also recognizes that in addition to factors within BC Hydro's control (e.g., program design), factors external to the utility (e.g., state of economy, Kyoto implications etc.) can significantly influence the Achievable Potential.

1.4 OVERVIEW OF APPROACH

To meet the objectives outlined above, the study was conducted within a highly iterative process that involved a number of well defined steps. At the completion of each step, BC Hydro reviewed the results and, as applicable, revisions were identified and incorporated into the interim results. The study then progressed to the next step.

A summary of the steps is presented below.

Step 1: **Develop Base Year Calibration Using Actual BC Hydro Billing Data**

- Data on industrial activity in BC Hydro's service area for the base year was collected, compiled and analyzed. Data sources included B.C. Statistics, BC Hydro's Load Forecasting Department, company web sites and annual reports and various consultant studies.
- Six subsectors used almost 80% of the electricity that BC Hydro sold to its industrial customers in fiscal year (FY) 2000/01. These were pulp and paper, wood products, chemical manufacturing, metal mining, coal mining and petroleum refining. The electricity use of BC Hydro's customers in these subsectors was modelled using the Intra-Sectoral Technology Use Model—Industry (ISTUM). ISTUM characterizes industrial electricity and other energy demands by technology and process type, enabling a rigorous portrayal of the various devices used by B.C. industry.
- ISTUM was run using the base year activity forecasts, and the model electricity usage results for the base year were compared with BC Hydro's actual billing data. Changes were made as required in the technologies represented in the model (e.g., market penetration, energy use coefficients, etc.) to ensure close correspondence between the model output and actual BC Hydro customer base year usage.

Step 2: **Develop Reference Case**

- Forecasts of industrial activity in BC Hydro's service area were obtained from the BC Hydro Load Forecasting department for the milestone years of 2005/06, 2010/11 and 2015/16.
- ISTUM was used to forecast the electricity demands of BC Hydro's largest industrial customers over a 15-year period, and it provided detailed results by subsector and equipment type.
- Industrial customers not represented in ISTUM were analyzed using separate spreadsheet-based models.
- These forecasts were combined to create overall industrial sector forecasts of electricity use for the milestone years. This Reference Case forecast provided the baseline technologies against which possible electrical efficiency measures could be evaluated.

Step 3: **Develop and Assess Energy Efficiency Upgrade Options**

- A list of electrical efficiency measures was compiled based on discussions with BC Hydro staff, with industry experts and through other research.
- Detailed cost and performance data were obtained for each measure.

- Energy efficiency upgrade options were analyzed for each electricity end use represented in ISTUM.
- The Cost of Conserved Energy (CCE)[13] was calculated for each upgrade option.

Step 4: **Estimate Economic Electricity Savings Potential**

- Economic data on current and forecast costs for new electricity generation were obtained from BC Hydro.
- The identified energy efficiency upgrade options from Step 3 were compared to the utility economic data.
- The combinations of energy efficiency upgrade options and equipment types where the cost of saving a kilowatt hour of electricity was equal to, or less than, the unit cost of new electricity generation were identified.[14]
- The economically attractive electrical efficiency measures from Step 3 were applied in ISTUM for each industry subsector
- The annual electricity consumption was calculated for each process type or industrial application where the economic efficiency measures were used.
- The industrial subsector's total electricity consumption, when all economic efficiency measures are used, was compared to the Reference Case consumption level and the electricity savings calculated. This was done for each industrial subsector.

Step 5: **Estimate Achievable Electricity Savings Potential**

- The electricity saving opportunities identified in the Economic Potential Forecast were "bundled" into a set of Actions.
- Action Profiles were created for each of the identified Actions that provide a "high-level" rationale and direction, including target technologies and sub-markets as well as key barriers and a broad intervention strategy.
- Historical achievable program results were reviewed and preliminary Action Assessment Worksheets were prepared.
- Consultations were held with Power Smart personnel, preliminary estimates were reviewed and general agreement was reached on the most likely and upper ranges of achievable potential.

Step 6: **Estimate Demand Impacts of Economic and Achievable Electricity Savings Potential**

- Utility peak periods were defined and the distribution of base year annual electricity use within each period was estimated, based on best available load data.
- Demand estimates were compared with best available utility system and sector load data.

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[13] The term CCE that is used in this study refers to the same methodology as was used in the original CPR. However, in the original CPR, the term Total Resource Cost (TRC) was used. In both CPRs program and administrative costs were excluded. Since the TRC normally includes program and administrative costs, it was considered clearer to use the term Cost of Conserved Energy in this effort. Adding 0.5 to 1 cent per kilowatt hour to the CCE used in this review would give a rough approximation of the TRC as it is usually calculated. Further detail on the CCE is provided in Section 4 (4.2.1).

[14] Further discussion of the cost of new electricity generation is provided in Section 5.2.

- Using the same approach as for the estimate of the base year, the average on-peak demand was calculated for the Reference Case as well as Economic Potential and Achievable Potential Forecasts.
- On-peak demand savings were calculated for the Economic and Achievable Potential Forecasts relative to the Reference Case.

Step 7: **Review Additional Technologies**

- A brief qualitative write up was prepared for those technologies that did not meet the study criteria for inclusion but could, nonetheless, provide additional savings under the appropriate conditions.

1.5 ANALYTICAL MODEL

The analysis of the Industrial Sector employed ISTUM to simulate the electricity and other energy demands of the major industrial subsectors (pulp and paper, wood products, chemical products, coal mining, metal mining and petroleum refining) in BC Hydro's service area. These subsectors together accounted for about 80% of total utility industrial sector sales in fiscal 2000/01.

The ISTUM model is an end-use computer model of the Industrial Sector. This model was used to analyze the industrial sector in BC Hydro's first Conservation Potential Review, completed in 1994. The Energy and Materials Research Group at Simon Fraser University has since used the model for a variety of studies. Since the model is used on an ongoing basis, this study has benefited from improvements made to ISTUM over the past decade.

Most recently, the Industry Table of the National Climate Change Program (NCCP) used the model to analyze measures for reducing greenhouse gas. This was one of 13 Issue Tables that the Climate Change Secretariat used to develop Canada's National Implementation Strategy in response to Kyoto. As a result, the model was calibrated to actual 1999 data, and both the model results and the major process and equipment inputs were subjected to extensive peer review. The current study benefits from these recent improvements.

The major "drivers" within ISTUM that determine electricity use are:

- Activity levels within each subsector (e.g., tonnes of mechanical pulp produced, tonnes of coal mined).
- Production processes employed (e.g., continuous versus batch processes).
- The type and efficiency of specific equipment (e.g., percentage of high efficiency versus standard efficiency motors, percentage of motors with adjustable speed drives, etc.).

The ISTUM model analyses a specific industrial subsector by treating the whole subsector as one plant. For example, the pulp and paper subsector is treated as one large integrated mill that produces all the market pulp and paper produced in the province. The model contains information on all the major equipment and processes that are used in the province to generate this final product. The main input to the model is the amount and type of paper and market pulp that is produced by this one plant. The model is then used to estimate the amount of pumping, process, fan and other types of end-use horsepower that is required to produce the specified product. The results cannot be used to adequately model any individual plant.

Smaller industrial subsectors were modelled separately under the category "Other Industry," which includes industry groups ranging from greenhouses to small, light manufacturing shops. Team members had previously developed an Excel model, based on the data from several hundred plant and energy audits and team member files, to analyze such smaller industry subsectors.

1.6 REPORT PRESENTATION

The remainder of this report is organized as follows:

- **Section 2** presents the results of and the specific tasks involved in developing the base year calibration.
- **Section 3** presents the Industrial Reference Case for the FYs 2000/01, 2005/06 and 2015/16.
- **Section 4** identifies and assesses technical options for improving electrical efficiency within the Industrial Sector.
- **Section 5** presents the Industrial Sector Economic Potential Forecast for the study period (FYs 2000/01 to 2015/16).
- **Section 6** estimates the proportion of savings identified in the Economic Potential Forecast that can realistically be achieved within the study period.
- **Section 7** estimates the demand impacts of the energy savings contained in the Economic and Achievable Potential Forecasts presented in Sections 5 and 6.
- **Section 8** provides a qualitative review of selected technologies that could become commercially available after 2005 but before 2015/16 to provide additional electricity savings.
- **Section 9** provides a summary of the study findings.
- **Section 10** lists sources and references.
- **Section 11** presents a glossary of terms used throughout this study.

2. BASE YEAR CALIBRATION, INDUSTRIAL SECTOR

2.1 INTRODUCTION

This section summarizes the results, assumptions and methodology employed in the development of the Base Year[15] calibration. The discussion is organized within the following subsections:

- Industrial Subsector Definition
- Equipment Inventory
- Industrial Activity
- Summary of Model Results
- Comparison with BC Hydro Billing Data
- Data Variances.

2.2 INDUSTRIAL SUBSECTOR DEFINITION

The industrial subsector definitions analysed in this study are the same as those in the original CPR study and include BC Hydro industrial customers served at both transmission and distribution voltages. The industrial subsectors are:

- Pulp and paper
- Wood products
- Chemical manufacturing
- Metal mining
- Coal mining
- Petroleum refining and
- Other industry (*see* Exhibit 2.1).

Some refinements to the original CPR were incorporated into the industrial subsector referred to as "Other Industry." The "Other Industry" category represents approximately 12% of the total BC Hydro industrial load and consists of industrial facilities not included in the major industrial subsectors. Exhibit 2.1 illustrates the large variety of industry types belonging to this category at the distribution and transmission service levels.

BC Hydro billing data provided the Base Year electricity consumption for the "Other Industry" category.

Because of the large variety of industry types, the "Other Industry" category was modelled outside of the ISTUM model using an Excel model developed previously by consultants. The break down of the base year electricity consumption for this subsector into different electricity service categories (i.e., pumping, air displacement, etc) was based on data from energy audits obtained from BC Hydro and from consultant files.

[15] The fiscal year 2000/2001 was selected for the base year, as this is the most recent period for which complete customer data are available. Additionally, the fiscal rather than calendar year was chosen as it was felt that this approach reduced potential data reporting overlap during December/January period when space heating electricity use is typically greatest.

Exhibit 2.1: Composition of "Other Industry" Category

Agriculture	Primary Metal
Fisheries and Trapping	Fabricated Metal
Forestry	Machinery
Food, Beverage, Tobacco	Transportation Equipment
Rubber and Plastic	Non-metallic Mineral
Leather, Textiles, Clothing	
Furniture and Fixtures	Pipeline Transport
Printing and Publishing	
Primary Metal	
Fabricated Metal	
Machinery	Irrigation
Transportation Equipment	
Electrical and Electronic	
Non-metallic Mineral Products	
Construction	
Other Manufacturing	

2.3 EQUIPMENT INVENTORY

As noted above, the production processes and specific equipment employed in each industrial sector are important determinants of overall electricity use. For this application, Willis Energy, in collaboration with industry experts, reviewed and updated the process and equipment inventory contained in the ISTUM model. The review was based on a combination of energy audits completed by BC Hydro and work that Willis has done for a number of B.C. companies.

(For further details on the individual process and equipment efficiency assumptions employed in ISTUM for the Base Year, *see* Appendix A.)

2.4 INDUSTRIAL ACTIVITY

Exhibit 2.2 summarizes the estimated activity (production) levels for the major industry subsectors in BC Hydro's service area. Data for the base year 2000/01 were obtained from a variety of sources, including industry association literature and web sites, provincial government statistics and company annual reports. In those cases where the firms provided only plant capacities, production levels were estimated according to the stated capacity and an assumed load factor, typically 75 to 80%, depending on the type of plant. These data were then compared for reasonableness with the 2005/06 activity forecasts provided by BC Hydro's Load Forecasting Department.

Exhibit 2.2: Base Year (2000/01) Industrial Activity by Subsector, for the BC Hydro Service Area

Wood Products (000 m^3)	
Lumber	32,034
Structural board	2,914
Plywood and veneer	1,519
Medium-density fibreboard (MDF)	210
Oriented strand board (OSB)	940
Particleboard	245
Pulp and Paper (000 t)	
Chemical pulp	5,060
Mechanical pulp	2,320
Recycled pulp	290
Newsprint/Directory	1,960
Tissue	80
Coated paper	188
Kraft, printing and writing	682
Metal Mines (t)	
Copper	235,000
Molybdenum	2,622
Gold (kg)	10,550
Silver	62
Coal (000 t) Metallurgical + Thermal	25,358
Chemicals (000 t)	
Sodium chloride	159
Sodium hydroxide	175
Hydrogen peroxide	36
Ammonia	200
Petroleum Refineries (m^3/day)	
Refined products	9,857

2.5 SUMMARY OF MODEL RESULTS

This section presents the results of the ISTUM runs for the Base Year 2000/01. The results are presented in the following exhibits:

- Exhibit 2.3 presents the model results for the total BC Hydro service area, broken out by region.
- Exhibit 2.4 presents the model results, for the total BC Hydro service area, broken out by subsector and by major end use.
- Exhibit 2.5 summarizes the electricity billing data employed for each of the subsectors contained in the "Other Industry" category.

Exhibit 2.3: Model Results—Base Year (2000/01) Electricity Consumption for Total BC Hydro Service Area by Region[16], (GWh/yr.)*

Service Region	Total Electricity Consumption (Net of Self Generation)
Lower Mainland	5,127
Vancouver Island	5,209
Interior	9,417
Total BC Hydro	**19,753**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 2.4: Model Results—Base Year (2000/01) Electricity Consumption for the Total BC Hydro Service Area by Subsector and End-use Service, (GWh/yr.)*

Service	Pulp and Paper	Mining[17]	Wood Products	Chemicals	Petroleum Refining	Other Industry	Total
Pumping Systems	4,388	240	13	123	382	196	5,342
Air Displacement Systems	1,636	19	271	4	19	307	2,256
Compression Systems	176	13	243	50	18	173	673
Conveyance	877	29	454	5	59	143	1,567
Process Equipment	5,817	2,358	1,804	17	1	557	10,554
Electrolysis	0	0	0	1,398	0	0	1,398
Process Heat	0	0	0	0	0	129	129
Light	37	223	21	56	10	147	494
Other	202	7	23	0	0	746	978
Subtotal	**13,133**	**2,889**	**2,829**	**1,653**	**489**	**2,397**	**23,391**
Self Generation	(3,638)	0	0	0	0	0	(3,638)
Total	**9,495**	**2,889**	**2,829**	**1,653**	**489**	**2,397**	**19,753**

* Results are measured at the customer's point of use and do not include line losses.

[16] A further breakdown of data by subsector is not provided for the industrial sector to ensure customer confidentiality.

[17] The mining subsector results include both coal (metallurgical and thermal) and metal mines as presented previously in Exhibit 2.2. In the case of Pulp and Paper, self-generated electricity is included for the purpose of reporting the complete energy consumption by the subsector.

Exhibit 2.5: Base Year (2000/01) Electricity Sales for "Other Industry," (GWh/yr.)*

Subsector	Base Year Sales
Agriculture	139
Fisheries and Trapping	76
Forestry	105
Food and Beverage	452
Rubber and Plastic	141
Leather, Textiles, Clothing	26
Furniture and Fixtures	32
Printing and Publishing	92
Primary Metal	50
Fabricated Metal	155
Machinery	40
Transportation Equipment	62
Electrical and Electronic	184
Non-metallic Mineral Products	68
Construction	127
Primary Metal	26
Fabricated Metal	33
Machinery	9
Transportation Equipment	103
Non-metallic Mineral	295
Pipeline Transport	87
Irrigation	95
Total	**2,397**

*Results are measured at the customer's point of use and do not include line losses.

2.6 COMPARISONS WITH BC HYDRO BILLING DATA

This section compares the actual BC Hydro billing data for each of the industry subsectors with the results generated by the ISTUM model. Exhibit 2.6, below, presents the comparison.

Exhibit 2.6: Base Year Electricity Consumption, (GWh/yr.), Comparison of Actual versus Model Estimates*

Subsector	BC Hydro Billing Information 2000/01	ISTUM Model Results
Pulp and Paper	9,144	9,495
Mines—Metal and Coal	2,718	2,889
Wood Products	2,492	2,829
Chemical and Chemical Products	1,786	1,654
Petroleum Refineries	496	490
Other	2,397	2,397
Total	**19,034**	**19,753**

*Results are measured at the customer's point of use and do not include line losses.

As illustrated in Exhibit 2.6, the ISTUM results compare quite well for the Industrial Sector as a whole. Overall, the modelled electricity consumption of 19,753 GWh/yr. is within about 3.8% of total industrial sales for the year 2000/01. Based on previous experience with ISTUM and this type of analysis, calibration to within 5% is considered reasonable.

Exhibit 2.6 also illustrates that the "Other Industry" category matches exactly the BC Hydro billing data. This exact match occurs because this industrial subsector was modelled outside of ISTUM using a custom spreadsheet model. Since the starting point for this model was the actual billing data for 2000/01, no calibration work was required.

2.7 DATA DISCREPANCIES

Most of the subsectors show a relatively close match between ISTUM estimates and BC Hydro billing data. However, the pulp and paper subsector, which shows the largest discrepancy, serves as a good example for the types of factors believed responsible for the gap between modelled results and billing data:

- The amount of self-generated electricity is estimated. This is necessary because, in some cases, customers consider the detailed data on the amount of electricity that industrial sites generate through co-generation, on-site hydro facilities, etc., to be confidential information.
- Due to the complexity of mill operations, operating efficiency levels can vary significantly from average values. The frequency and duration of planned and unplanned shutdowns also affect operating levels.
- Often many types of products are included in specific product categories defined within ISTUM, with each type of product having a unique per unit electricity consumption. For example, ISTUM calculates the electricity required to produce coated paper within a

single aggregate category that includes many types of coated paper. However, the types and amounts of coated paper produced within the industry are continually changing, and this, in turn, affects electricity consumption.

- Changes in tree species and the condition of wood chips fed to mechanical pulp mills can affect electricity consumption. Similarly, the dimensions of trees sent to sawmills affect both electricity usage and the amount and quality of wood residue available as fuel for industrial self-generation.
- The market quality of pulp and paper varies according to market conditions. Mills change their mechanical refining operations to produce different quality products. This, in turn, affects electricity consumption.

3. REFERENCE CASE

3.1 INTRODUCTION

This section presents the Industrial Sector Reference Case for the study period (FY 2000/01 to 2015/16). The Reference Case begins with the base year calibration presented in Section 2 and estimates the expected level of electricity consumption that would occur over the study period in the absence of new Power Smart initiatives or rate changes.[18] The Reference Case, therefore, provides the point of comparison for the subsequent calculation of remaining economically attractive electricity savings opportunities. The discussion is organized according to the following headings:

- Forecast Production Activity Levels
- "Natural" Changes to Electricity Intensity
- Summary of Model Results
- Comparison with BC Hydro Forecast
- Assessment of Variances.

3.2 FORECAST PRODUCTION ACTIVITY LEVELS

The first step in building the Reference Case involved estimating production activity, by sector, for the milestone FYs 2005/06, 2010/11 and 2015/16. Once production activity forecasts are input into the model, ISTUM calculates the annual energy used by the industrial processes and installed equipment for each subsector.

Exhibit 3.1 shows the actual activity for the Base Year, as discussed in Section 2.4. BC Hydro's Load Forecast Department provided the forecast subsector production activity data for the model years.

It is acknowledged that the growth of industrial electricity consumption in British Columbia has been declining, reflecting British Columbia's general shift from a resource-based to a service-based economy. The decline in this Reference Case also reflects modelling assumptions including: the anticipated mix and quantity of future industrial products and sub-products; future technological and other changes that impact the electrical intensity of industrial production; and, the level of self-generation adopted by industry.

[18] Some limited residual program influences remain from the earlier Power Smart initiatives.

Exhibit 3.1: B.C. Industrial Activity Forecast, for the BC Hydro Service Area

Subsector	2000/01 Actual	2005/06 Forecast	2010/11 Forecast	2015/16 Forecast
Wood Products (000 m^3)				
Lumber	32,034	33,819	33,276	29,146
Structural board	2,914	3,795	4,240	4,490
Plywood and veneer	1,519	1,600	1,600	1,600
MDF	210	220	500	750
OSB	940	1,440	1,440	1,440
Particleboard	245	535	700	700
Pulp and Paper (000 t)				
Chemical pulp	5,060	5,408	4,002	3,797
Mechanical pulp	2,320	2,136	2,264	2,141
Recycled pulp	290	256	145	145
Newsprint/Directory	1,960	982	962	985
Tissue	80	146	148	149
Coated paper	188	188	304	307
Kraft, printing and writing	682	680	680	680
Metal Mines (t)				
Copper	235,000	254,000	254,000	176,000
Molybdenum	2,622	2,822	2,822	450
Gold (kg)	10,550	7,655	7,655	20,299
Silver	62	65	65	32
Coal Mines (000 t)				
Metallurgical and thermal	25,358	26,000	26,000	26,000
Chemicals (000 t)				
Sodium chlorate	159	200	225	225
Sodium hydroxide	175	200	225	225
Hydrogen peroxide	36	40	50	50
Ammonia	200	200	200	200
Methanol	120	500	0	0
Oxygen	35	N/A	N/A	N/A
Petroleum Refineries (m^3/day)				
Refined products	9,857	9,857	9,857	9,857

Source: BC Hydro Base Year Load Forecast

3.3 NATURAL CHANGES TO ELECTRICAL INTENSITY

The next step in building the Reference Case involved estimating major equipment and/or process efficiency changes that were likely to occur within each of the subsectors in the absence of new Power Smart initiatives. Complex production processes and equipment inventories serve each of the major industries addressed by this study. Moreover, specific investments that companies undertake within a given subsector are subject to a wide range of influencing factors. Detailed analysis of such factors for each subsector lies well beyond the scope of this study.

For the Reference Case ISTUM estimated the energy that would be used in each industrial subsector for each of the forecast years. The model accounted for activity level changes (e.g., the tonnes of paper produced in 2015/16 is estimated to be less than in 2000/01). The model also accounted for structural changes that may occur over the period (e.g., increased production of coated paper and decreased production of newsprint). The model also assumed that industry would invest in efficiency improvement over the period but that these decisions would be based on industry's typical discount rate (usually in the range of 3 to 5%).

The following discussion provides an overview of broad industry trends that are expected to affect electrical intensity and that have been incorporated within the ISTUM Reference Case. The discussion is presented by industry subsector.

3.3.1 Pulp and Paper

Over the study period, the calculated electrical intensity of the pulp and paper industry of British Columbia (B.C.) is expected to continue fluctuating, as it has in the past. The most significant process changes that are expected to affect electrical intensity over the study period include:

- Environmental controls—increased tertiary treatment of effluent, electrostatic precipitators, etc.
- Wood residue handling—increased use as feed-stock for on-site energy production or for shipment off site.
- Fibre recovery—delignification, improved sorting and increased handling of logs.
- Computer controls and automation—introduction of advanced systems.
- More electricity-intensive chemi-thermal mechanical pulp—replacement of stoneground capacity.

In addition to the above process changes, the continued penetration of adjustable speed drives (ASDs), particularly with respect to new installations or plant upgrades, is expected to affect overall electricity use in this subsector. As for existing pumping systems, given the high cost of retrofits and the perceived operating risk of changing systems that are working reliably, it is not expected that a significant number of ASD retrofits will occur naturally.

3.3.2 Mining

During the study period, a few large mines are expected to affect electricity use in B.C.'s mining (metal and coal) industry. The opening of one new mine is expected to account

for increased electricity use by the subsector; however, anticipated mine closures will in time offset this increase.

Declining mineral content is another key factor affecting electricity use in this subsector, as larger volumes of ore require processing to obtain the same amount of a given mineral. This increased processing requirement thus offsets increased energy efficiency.

Over the study period, pumping and conveyance system efficiencies in this subsector benefit from the same application of ASDs and belt conveyers as in the pulp and paper sector. No other significant changes to the electrical efficiency within this sector have been included in the Reference Case.

3.3.3 Wood Products

Increased penetration of computer controls in the mills will allow the matching of mill output to market demand on a real time basis, which will in turn result in maximum grade product from raw logs. This, along with reduced wood losses, will lead to increased product output. The final demand for electricity will therefore fluctuate according to final product mix (size of logs and species of logs processed) and the number of mill shifts per day, etc.

The following process changes have been incorporated into the ISTUM Reference Case:

- Increased wood residue handling
- Increased coastal lumber drying
- Increased computer controls for head rigs, trim saws, planers, lumber-finishing and oriented strand board (OSB) and plywood production.

3.3.4 Chemicals and Chemical Products

The chemical industry can be considered a mature industry. While energy cost-saving opportunities continue to be of interest to the industry, little opportunity exists for major improvements in electricity efficiency. Despite energy cost saving opportunities such as fuel substitution, and the capture and use of low-grade waste heat, the electrical intensity of the chemical subsector is assumed to increase over the study period. The following process changes have been incorporated into the ISTUM Reference Case:

- Changes in electrolysis systems (for example, moving from mercury to diaphragm cells for the production of caustic/chlorine and from metal anode to graphite cells for the production of sodium chlorate).
- Installation of computer control systems for the evaporator train.
- Installation of larger-scale evaporators.

3.3.5 Refineries

No major process changes are expected over the study period. Since no new refineries are being constructed in Canada, no new breakthrough technology is expected to improve refinery energy efficiency in any significant way. Lower sulphur levels and ongoing

gasoline reformulation will result in more process units which will, in turn, mean more electricity being used for mass transfer (i.e., pumping, compression). In addition to actual volume of crude refined, the amount of energy used is also a function of the feedstock characteristics and the final product mix. Light, sweet (i.e., low-sulphur-content) crude would require less energy to process than would heavy, high-sulphur-content oil.

Potential process improvements exist that could be applied more extensively to refineries to reduce energy use and operating costs. However, under existing conditions, it is not expected that the refinery owners will invest in these potential improvements due to the age of the facilities and their perception of the competitive risks confronting them. Therefore, these improvements are not included in the Reference Case.

3.4 SUMMARY OF MODEL RESULTS

This section presents the results of the ISTUM runs for the Reference Case in milestone years FYs 2005/06, 2010/11 and 2015/16. The results are presented in the following exhibits:

- Exhibit 3.2 presents the model results for the total BC Hydro service area, broken out by region and milestone year.
- Exhibits 3.3 through 3.5 present the model results by milestone year, for the total BC Hydro service area, broken out by subsector and by major end use.[19]

As discussed previously, self-generated energy is reported for the sake of completeness in terms of the total amount of energy required in the production of pulp and paper. The self-generated energy is netted out of the reported total, so that the model results more closely represent the amount of electricity purchased by the subsector.

The "Other Industry" subsector includes the remaining transmission and industrial distribution customers, along with transmission and distribution pipeline and irrigation customers. The BC Hydro billing system classifies the pipeline and approximately half of the irrigation customers as commercial accounts; nevertheless, their large motor loads make them industrial in character, and they are therefore included in the "Other Industry" category, as presented previously in Exhibit 2.1.

Exhibit 3.2: Model Results—Electricity Consumption for the Total BC Hydro Service Area, by Region and Milestone Year, (GWh/yr.)*

Milestone Year	Lower Mainland	Vancouver Island	Interior	Total
2005/06	4,533	5,067	9,562	19,162
2010/11	4,626	4,623	9,796	19,045
2015/16	4,609	4,349	8,863	17,821

*Results are measured at the customer's point of use and do not include line losses.

[19] The mining subsector results include both coal (metallurgical and thermal) and metal mines (*see* Exhibit 2.2). In the case of Pulp and Paper, self-generated electricity is included for the purpose of reporting the complete energy consumption by the subsector.

Exhibit 3.3: Model Results—Electricity Consumption in Forecast Year 2005/06 for the Total BC Hydro Service Area, by Subsector and End-use Service, (GWh/yr.)*

Service	Pulp and Paper	Mining	Wood Products	Chemicals	Petroleum Refining	Coal	Other Industry	Total
Pumping Systems	3,951	117	17	182	302	116	213	**4,898**
Air Displacement Systems	1,603	12	285	9	18	200	334	**2,461**
Compression Systems	160	6	256	94	16	13	188	**733**
Conveyance	847	18	467	7	59	19	155	**1,572**
Process Equipment	5,417	1,755	1,839	23	16	152	605	**9,807**
Electrolysis	0	0	0	1,763	0	0	0	**1,763**
Process Heat	0	0	0	0	0	0	140	**140**
Light	28	103	21	55	3	51	160	**421**
Other	152	2	28	0	1	62	811	**1,056**
Self-generation	(3,689)	0	0	0	0	0	0	**(3,689)**
Total	**8,469**	**2,013**	**2,913**	**2,133**	**415**	**613**	**2,606**	**19,162**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 3.4: Model Results—Electricity Consumption in Forecast Year 2010/11 for the Total BC Hydro Service Area, by Subsector and End-use Service, (GWh/yr.)*

Service	Pulp and Paper	Mining	Wood Products	Chemicals	Petroleum Refining	Coal	Other Industry	Total
Pumping Systems	3,221	114	18	202	304	116	239	**4,214**
Air Displacement Systems	1,272	11	282	9	18	196	375	**2,163**
Compression Systems	145	6	255	99	17	13	211	**746**
Conveyance	712	28	466	8	65	19	174	**1,472**
Process Equipment	5,184	1,889	1,875	25	11	151	680	**9,815**
Electrolysis	0	0	0	2,090	0	0	0	**2,090**
Process Heat	0	0	0	0	0	0	157	**157**
Light	33	103	20	54	3	48	179	**440**
Other	181	2	30	0	1	61	910	**1,185**
Self-generation	(3,238)	0	0	0	0	0	0	**(3,238)**
Total	**7,510**	**2,153**	**2,946**	**2,487**	**419**	**604**	**2,926**	**19,045**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 3.5: Model Results—Electricity Consumption in Forecast Year 2015/16 for the Total BC Hydro Service Area, by Subsector and End-use Service, (GWh/yr.)*

Service	Pulp and Paper	Mining	Wood Products	Chemicals	Petroleum Refining	Coal	Other Industry	Total
Pumping Systems	3,049	75	19	201	310	116	255	**4,025**
Air Displacement Systems	1,172	8	248	9	20	192	400	**2,049**
Compression Systems	138	4	227	98	18	13	225	**723**
Conveyance	658	31	415	8	72	18	186	**1,388**
Process Equipment	4,797	1,486	1,680	25	6	151	726	**8,871**
Electrolysis	0	0	0	2,162	0	0	0	**2,162**
Process Heat	0	0	0	0	0	0	168	**168**
Light	33	68	18	50	3	44	192	**408**
Other	183	2	27	0	1	60	972	**1,245**
Self-generation	(3,219)	0	0	0	0	0	0	**(3,219)**
Total	**6,811**	**1,674**	**2,634**	**2,553**	**430**	**594**	**3,125**	**17,821**

*Results are measured at the customer's point of use and do not include line losses.

3.5 COMPARISON WITH BC HYDRO FORECAST

This section compares the BC Hydro load forecast data with the results generated by the ISTUM model. Exhibit 3.6 compares the results of the ISTUM reference model run with the BCH forecast for the total BC Hydro service area.

Exhibit 3.6: Actual versus Model Estimates—Electricity Consumption, (GWh/yr.)

	2005/06	2010/11	2015/16
BC Hydro	18,544	20,640	20,602
ISTUM	19,162	19,045	17,821

As the above exhibit illustrates, the relationship of ISTUM and the BC Hydro forecasts varies over the study period. For the year 2005/06, ISTUM indicates 3% more energy use than does the BC Hydro forecast total whereas, for 2010/11 and 2015/16, ISTUM results are 8% and 13% less, respectively, than the BC Hydro forecast total. These differences are the result of assumptions and modelling methodologies used to produce the forecast.

It is important to note that ISTUM provides one future scenario of industrial energy consumption, which assumes that no additional energy conservation programs will be introduced in the future (i.e., the Reference Case). In Chapters 5 and 6, this is compared to other future energy scenarios assuming the adoption of varying levels of conservation (i.e., the economic potential and the achievable potential). As such, it is the difference between these future electricity consumption scenarios that is important in determining the energy conservation potential rather than any absolute quantity of electric energy consumed.

3.6 ASSESSMENT OF TRENDS

A review of the ISTUM results was undertaken to better understand why the changes in electricity use occur in the milestone years. Exhibit 3.7 presents the results of that review. As illustrated in Exhibit 3.7, changes in electricity use are linked to three potential effects. They are as follows:

- Activity Effect—Changes in electricity use are due to changes in overall production activity levels (e.g., the tonnes of paper produced).
- Structural Effect—Changes in electricity use are due to changes in sub product mix (e.g. the type of coated paper), which may be more/less energy intensive than previous milestone year sub product mix.
- Energy Efficiency Effect—Changes in electricity use are due to net changes in the energy efficiency of producing the product. If the Energy Efficiency Effect in Exhibit 3.7 is positive, electrical efficiency has declined; if negative, efficiency has improved.

Exhibit 3.7: Electricity Use Efficiency Indicators

Subsector	Units	2000/01	2005/06	2010/11	2015/16
Wood					
Activity (Lumber and Structural Board)	$000m^3$	34,948	37,614	37,516	33,636
ISTUM Electricity Consumption	kWh*E06	2,516	2,880	2,882	2,555
ISTUM Electricity Intensity	MWh/000 m^3	71.99	76.57	76.82	75.96
Change In Electricity	kWh*E06	0	364	366	39
Change due to:					
Activity Effect	kWh*E06	0	192	185	-94
Structure Effect	kWh*E06	0	160	169	139
Energy Efficiency Effect [20]	kWh*E06	0	12	12	-5
Pulp and Paper					
Activity (Pulp Production only)	(000 tonnes)	7,670	7,800	6,411	6,083
ISTUM Electricity Consumption	kWh*E06	9,495	8,469	7,510	6,811
ISTUM Electricity Intensity	MWh/000 t	1,222	1,086	1,171	1,103
Change In Electricity	kWh*E06	0	-902	-1,861	-2,660
Change due to:					
Activity Effect	kWh*E06	0	159	-1,538	-1,939
Structure Effect	kWh*E06	0	-1,043	-386	-909
Energy Efficiency Effect [19]	kWh*E06	0	-18	63	188
Mines—Metal					
Activity (Copper and Molybdenum)	(000 tonnes)	237,622	256,822	256,822	176,450
ISTUM Electricity Consumption	kWh*E06	2,291	2,013	2,153	1,674
ISTUM Electricity Intensity	MWh/000 t	10	8	8	9
Change In Electricity	kWh*E06	0	-278	-138	-617
Change due to:					
Activity Effect	kWh*E06	0	185	185	-590
Structure Effect	kWh*E06	0	-428	-299	-37
Energy Efficiency Effect [19]	kWh*E06	0	-35	-24	9
Mines—Coal					
Activity	(000 tonnes)	25,358	26,000	26,000	26,000
ISTUM Electricity Consumption	kWh*E06	598	613	604	594
ISTUM Electricity Intensity	MWh/000 t	24	24	23	23
Change In Electricity	kWh*E06	0	15	6	-4
Change due to:					
Activity Effect	kWh*E06	0	15	15	15
Structure Effect	kWh*E06	0	0	-9	-19
Energy Efficiency Effect [19]	kWh*E06	0	0	0	0
Chemicals and Chemical Products					
Activity	(000 tonnes)	690	1,140	700	700
ISTUM Electricity Consumption	kWh*E06	1,654	2,133	2,487	2,553
ISTUM Electrical Intensity	MWh/000 t	2,397	1,871	3,553	3,647
Change In Electricity	kWh*E06	0	479	833	899
Change due to:					
Activity Effect	kWh*E06	0	1,079	24	24
Structure Effect	kWh*E06	0	-363	797	863
Energy Efficiency Effect [19]	kWh*E06	0	-237	12	13
Petroleum Refineries					
Annual Activity	$000m^3$	3,450	3,450	3,450	3,450
ISTUM Electricity Consumption	kWh*E06	490	415	419	430
ISTUM Electricity Intensity	MWh/000 m^3	142	120	121	125
Change In Electricity	kWh*E06	0	-75	-71	-60
Change due to:					
Activity Effect	kWh*E06	0	0	0	0
Structure Effect	kWh*E06	0	-75	-71	-60
Energy Efficiency Effect [19]	kWh*E06	0	0	0	0

[20] If the Energy Efficiency Effect in Exhibit 3.7 is positive, electrical efficiency has declined; if negative, efficiency has improved.

To further assist the understanding of the trends shown in Exhibit 3.7, a brief explanation of some of the assumptions imbedded in the modelled industries is presented below.

3.6.1 Wood Products

The ISTUM results reflect increased wood residue handling and improved efficiency of motors, pumps and fans in the mills, along with increased control integration. Given the high number of low-horsepower motors in the industry, electrical efficiency in the wood product sector will benefit from ASD technology.

3.6.2 Pulp and Paper

ISTUM forecasts a net decline in overall electricity use intensity during the study period. On the one hand, consumption is expected to increase due to additional pumping for effluent treatment, replacing stoneground pulping with thermomechanical pulping, increased chip refining due to improved fibre recovery, increased wood residue handling and increased installation and production of oxygen (for bleaching and effluent treatment) on site. This increase is partially offset by efficiency gains, which include improved debarking equipment, more-efficient batch processing, more efficient refiners and new computer controls.

Production levels drive ISTUM. The forecast drop in activity results in a reduction in debarking, processing, refining, and drying and reduced chemical use.[21]

3.6.3 Metal and Coal Mines

The demand for the final product drives ISTUM, which uses industry standards and research data to determine the volume of material required out of the ground to provide, in this case, the coal or metal end product. ISTUM forecasts relatively little change in overall electrical intensity for both the metal and coal mine subsectors. Note that ISTUM is forecasting a significant reduction in electricity use within this sector over the study period. This is largely due to a reduction in mining activity.

3.6.4 Chemicals and Chemical Products

ISTUM energy use intensity increases in keeping with the changing mix of chemical products. The percentage of the electrochemical mix within the subsector is expected to increase, and as electrochemicals have a higher kWh/tonne value; ISTUM forecasts an increase in overall unit intensity for the subsector.

[21] Note that sodium chlorate produced by B.C. chemical manufacturing plants is converted to chlorine dioxide for pulp bleaching at the pulp mill site. It requires over 300kWh/tonne of chlorate delivered to the mill to produce chlorine dioxide; this includes chlorate for chiller requirements.

3.6.5 Petroleum Refineries

Key assumptions within ISTUM include those around process improvements (e.g. distillation system pumping or increased use of efficient hydraulic feed for hydrocracking) and the quality of crude oil. Both of these can have a significant impact on the refinery process and electricity use.

4. ENERGY EFFICIENCY UPGRADE OPTIONS

4.1 INTRODUCTION

This section identifies and assesses technical options for improving energy efficiency within the Industrial Sector. The section is organized as follows:

- Approach and Definitions
- Summary of Results
- Technology Descriptions.

4.2 APPROACH AND DEFINITIONS

The methodology used in this study involves analyzing systems rather than individual components. Most research into energy efficiency in industry has focused on electric motors and electronic adjustable speed drives, ignoring the driven components that make up the balance of a motor system. Although electric motors provide substantial remaining conservation potential, various reports and the results of BC Hydro's Power Smart effort to date indicate that most of the remaining conservation potential is associated with the equipment being driven by the electric motors. Accordingly, the efficiency upgrades for the industrial sector study focus on the transformation of relatively inefficient systems to efficient systems, whether the system is used for pumping, air displacement, compressed air, conveyance or refrigeration system. The results reflect more than the simple replacement of inefficient components with efficient ones.

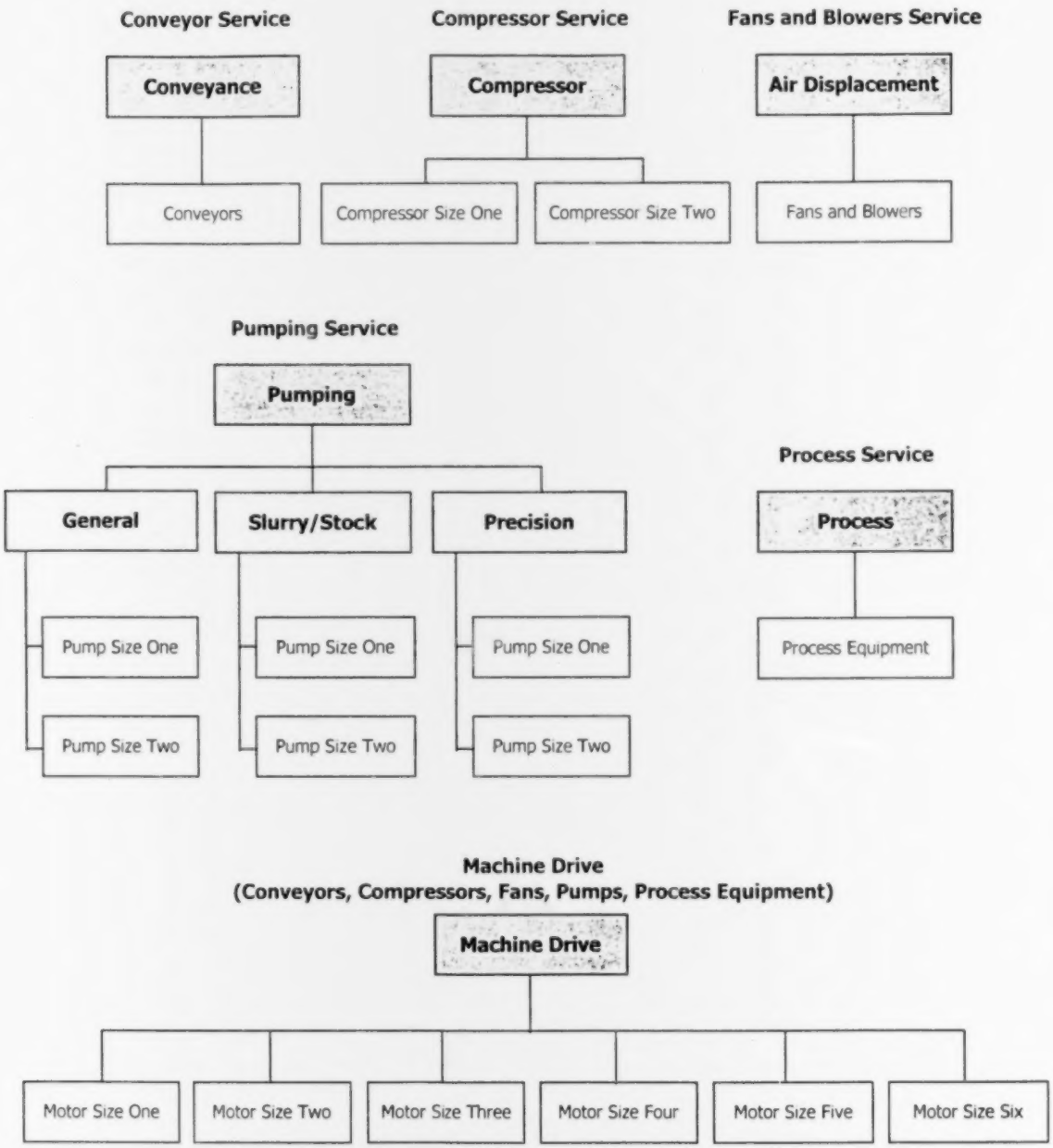
The ISTUM model works with the following five motor systems (or motor system end uses):

- Pumping
- Air displacement (fans and blowers)
- Compression
- Conveyance
- Process drive.

The Process drive category comprises all electrically driven technologies that are unique to a given production process, hence the term "process". These technologies would include, for example, mechanical pulpers, mineral ore grinders, and wood saws.

Exhibit 4.1 illustrates the energy flow model of motor systems that is used within ISTUM. ISTUM calculates the quantity of different types of energy service that are required to generate a given amount of product. For example, in the Pulp and Paper subsector, ISTUM determines the amount of air compressor or pumping horsepower that is required to produce a given amount of paper product. ISTUM simulates five different end use services, all of which are machine driven with electric motors. Conveyance, compressors, air displacement, and pumping are four of the end-use services. The fifth is a service specified for the processes within each industrial subsector. ISTUM calculates all the various sizes of electric motors that are needed to drive conveyors, compressors, fans, pumps and process equipment.

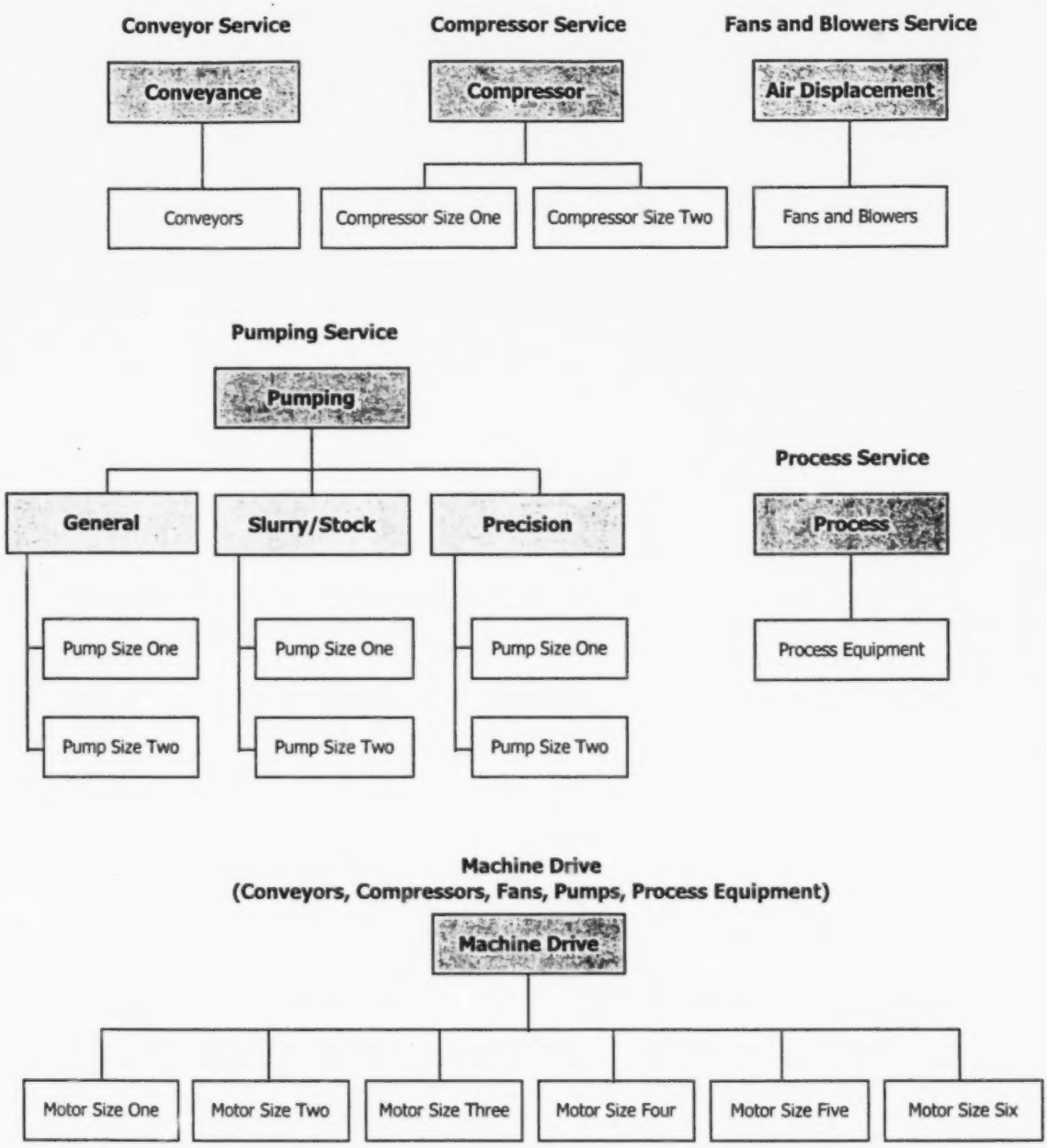
Exhibit 4.1: Energy Flow Model of Motor Systems



The motor group is disaggregated by size to account for efficiency differences between each size of motor and other variables used to define motors within the model.

Pumping, air displacement, compression and conveyance systems have been represented as packages within ISTUM, and the components of each system are associated with key end uses.

Exhibit 4.1: Energy Flow Model of Motor Systems



The motor group is disaggregated by size to account for efficiency differences between each size of motor and other variables used to define motors within the model.

Pumping, air displacement, compression and conveyance systems have been represented as packages within ISTUM, and the components of each system are associated with key end uses.

For example, a pumping system consists of a pipe, throttle and speed control device. In the model, there are at least two types of systems:

- The least-efficient system, comprising all the least-efficient components
- The most-efficient system, comprising the most-efficient components.

Moving from a relatively inefficient to an efficient system can involve modifications to a number of individual components. In a compressed air system, for example, an inefficient system can consist of a throttling type of control, a high-pressure drop, poorly laid out distribution system and inefficient end-use equipment. On the other hand, an efficient system might consist of a variable speed compressor, an optimized distribution system and no inefficient end-use equipment. Exhibit 4.2 in the following subsection (*see* Section 4.3) analyzes the cost and associated electricity savings of moving from a typical inefficient system to a typical efficient system for different sizes and types of systems.

In addition to the motor systems noted above, there are other industrial processes—for example, pulp refiners, paper machines and mining ore size reduction equipment—that are major consumers of electricity. In ISTUM, they fall into the process equipment category. Large process equipment involves a relatively small number of equipment units. For example, 91 pulp refiners represent 5,476 GWh/yr. of electricity consumption, or 25% of the total industrial load. These units are all custom-tailored to a given mill with a particular type of feedstock and, consequently, do not lend themselves easily to generalized estimates of cost or energy savings potential.

ISTUM calculates the economically attractive energy saving potential for process equipment by determining which units would be replaced by more efficient systems given specified selection criteria. Normally, companies select a particular type of equipment for production reasons. However, different types of equipment do have significantly different energy consumption characteristics, and energy cost is a consideration in selecting equipment. Conservation programs targeting these systems usually calculate the CCE (*see* below) on a project-by-project basis. For this study, the analysis of process equipment efficiency upgrades is included within ISTUM and within the overall results presented in later sections of this report; however, due to the greater complexity of the process equipment, it is not possible to provide useful estimates of cost and savings for a "typical system" in the summary tables provided in the following Section 4.3.

4.2.1 Cost of Conserved Energy

Exhibit 4.2 in Section 4.3 provides an estimate of both the level of annual electricity savings and the cost associated with implementation of the identified energy efficiency upgrades. The cost is expressed as the Cost of Conserved Energy (CCE).[22] The CCE for an energy efficiency upgrade is defined as the annualized incremental cost of the upgrade measure divided by the annual energy savings achieved, excluding any administrative or program costs required to achieve full use of the technology or measure. All cost information presented in this section and in the accompanying tables (*see* Appendix B) is in constant (2002) dollars.

[22] The term CCE that is used in this study refers to the same methodology as was used in the original CPR. However, in the original CPR, the term Total Resource Cost (TRC) was used. In both CPRs program and administrative costs were excluded.

The CCE provides a basis for the subsequent selection of measures to be included in the Economic Potential Forecast (*see* Section 5). The CCE is calculated according to the following formula:

$$\frac{C_A + M}{S}$$

Where:

C_A is the annualized installed cost
M is the incremental annual cost of operation and maintenance (O & M)
S is the annual kWh energy savings.

And A is the annualization factor.

$$A = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where:

i is the discount rate
n is the life of the measure.

The CCE summary tables presented in section 4.3 show both "incremental" and "full" installed costs for the measures or technologies, as applicable. If the measure or technology is installed in a new facility, or at the point of natural replacement in an existing facility, then the "incremental" cost of the efficient measure versus the cost of the baseline technology is used.

If a more efficient model replaces an operating piece of equipment prior to the end of its life, then the "full" cost of the efficient measure is used. In both cases, the costs of the measures are annualized according to the number of years of equipment life and the discount rate, and the costs incorporate applicable changes in annual O & M costs.

The annual saving associated with the efficiency measure is the difference in annual electricity consumption with and without the measure. The CCE summary tables show two savings: "without line losses" and "with line losses." The first savings estimate is the annual electricity savings that occur at the customer's meter. The second savings estimate takes into account BC Hydro system losses and is the value used to calculate the CCEs.

4.2.2 System Losses

For this study, system losses are 7%, including 3% area transmission losses and 4% distribution system losses. System losses are used in two areas of the study. First, losses are used in the calculations shown in the CCE Summary Table (*see* Exhibit 4.2). Since more than 77% of the industrial load is served at transmission voltages, the CCE

calculations incorporate 3% losses.[23] Losses are also used in the calculation of demand impacts of the potential electricity savings (*see* Chapter 7).

4.2.3 Discount Rate

The CCE calculation is sensitive to the chosen discount rate. In the CCE calculations, three discount rates are shown: 6%, 8% and 10%. Based on the recommendation of BC Hydro's Energy Planning Department, the 8% (net-of-inflation or real) discount rate was used for the primary CCE calculation. The CCEs were also calculated using the 6% and 10% discount rates to provide a sensitivity analysis.[24]

4.3 SUMMARY OF RESULTS

Exhibit 4.2, which summarizes the calculated CCEs, is organized according to the different types of motor systems and their size categories.

4.3.1 Technology Upgrade Options

For each motor system, Exhibit 4.2 shows the cost of moving from a less-efficient to a more-efficient system, along with associated savings. For example, savings and costs for a more-efficient pump system will involve calculating combined savings and costs for upgrading the drive system, control method and distribution system.

CCEs for motors and lighting are calculated for specific units of equipment, as opposed to the system approach. For example, the CCE for converting from a standard Metal-Halide to a Pulse-start lamp are included.

For each end use addressed in this study, Exhibit 4.2 shows the options for providing the same level of energy service but with greater efficiency.

4.3.2 Cost of Conserved Energy

The CCEs[25] are presented for three discount rates, as applicable, on a "full cost" and/or "incremental" installation basis.

As illustrated in Exhibit 4.2, a wide range of energy efficiency upgrade options provides opportunities for energy savings for each of the major industrial systems and end uses. The rest of this chapter presents further detail on each of the systems and end uses shown in Exhibit 4.2.

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[23] This approach omits bulk transmission losses of 5%; however, this is consistent with the approach being applied to other possible electricity options, such as small-scale renewable electricity. It is also consistent with the general assumption that the most likely future electricity supply options will occur at the regional levels rather that at remote sites, such as the historical large-scale hydroelectric developments.

[24] Arguably, the 8% social opportunity of capital, estimated in 1989, may be a different value today. However, in the absence of a comprehensive review, the 8% was recommended for this CPR to reinforce the understanding that the discount rate is the social opportunity cost of capital.

[25] Technology costs typically decline as they gain greater market share, which results in a lower CCE. Where applicable, these mature technology costs have been estimated and have been identified in the technology cost information provided.

Exhibit 4.2: CCE Summary Table—Savings and Costs Per System

Systems and End Uses	Efficient Measures	Savings per System		Costs per System ($)			Life Years	CCEs (¢/kWh)					
		Annual kWh without line losses	Annual kWh with line losses	Incremental Cost	Full Cost	Incremental O&M		D.R = 6.00%		D.R = 8.00%		D.R = 10.0%	
								Full	Incr.	Full	Incr.	Full	Incr.
Pump Systems	Small Centrifugal Pumping Systems (1—100 hp*)	40,640	41,859	$11,025	$14,500	$73	20	3.19	2.47	3.70	2.86	4.24	3.27
(Drive System, Control Method, Distribution System, Efficient Pump, Pump System End-use Efficiency)	Small Rotary Pumping Systems (1—100 hp)	33,465	34,469	$16,200	$27,350	$137	20	7.32	4.50	8.48	5.18	9.72	5.92
	Small Reciprocating Pump Systems (1—100 hp)	37,243	38,360	$18,025	$30,425	$152	20	7.31	4.49	8.47	5.18	9.71	5.92
	Large Centrifugal Pump Systems (> 100 hp)	407,976	420,215	$71,200	$84,800	$340	20	1.84	1.56	2.14	1.81	2.45	2.07
	Large Rotary Pump Systems (> 100 hp)	332,488	342,463	$89,200	$132,800	$664	20	3.57	2.46	4.14	2.85	4.75	3.25
	Large Reciprocating Pump Systems (>100 hp)	367,032	378,043	$98,200	$146,400	$732	20	3.57	2.46	4.14	2.84	4.74	3.24
Air Displacement Systems	Backward Inclined Fan System	44,394	45,726	$21,350	$32,550	$163	20	6.56	4.43	7.61	5.11	8.72	5.84
(Drive System, Control Method, Distribution System, Fan System End-use Efficiency)	Radial Fan System	41,353	42,594	$19,850	$30,300	$152	20	6.56	4.42	7.60	5.10	8.71	5.83
	Airfoil Fan System	44,394	45,726	$22,750	$34,750	$174	20	7.01	4.72	8.12	5.45	9.31	6.22
	Vaneaxial/Tubeaxial (VA/TA) Fan System	38,313	39,462	$17,900	$26,150	$131	20	6.11	4.29	7.08	4.95	8.12	5.66

*Horsepower

Exhibit 4.2 (continued)

Systems and End Uses	Efficient Measures	Savings per System		Costs per System ($)			Life Years	CCEs (¢/kWh)					
		Annual kWh without line losses	Annual kWh with line losses	Incremental Cost	Full Cost	Incremental O&M		D.R = 6.00%		D.R = 8.00%		D.R = 10.0%	
								Full	Incr.	Full	Incr.	Full	Incr.
Compressor Systems	Small Centrifugal Compressor System (1—100 hp)	38,444	39,597	$14,500	$34,050	$170	20	7.93	3.62	9.19	4.16	10.53	4.73
(Drive System, Control Method, Distribution and Storage, Efficient Compressors, Compressed Air End Use)	Small Double-acting Reciprocating System (1—100 hp)	39,485	40,670	$15,200	$36,750	$184	20	8.33	3.71	9.66	4.26	11.07	4.84
	Small Rotary Screw Compressor System (1—100 hp)	37,743	38,875	$11,100	$24,550	$491	20	6.77	3.75	7.70	4.17	8.68	4.62
	Small Single-acting Reciprocating System (1—100 hp)	36,001	37,081	$10,600	$23,400	$468	20	6.76	3.75	7.69	4.17	8.67	4.62
	Large Centrifugal System (> 200 hp)	173,271	178,469	$44,600	$83,000	$416	20	4.29	2.41	4.97	2.78	5.70	3.17
	Large Double-acting Reciprocating System (> 200 hp)	176,522	181,818	$45,000	$87,000	$436	20	4.41	2.40	5.11	2.76	5.86	3.15
	Large Rotary Screw System (> 200 hp)	169,554	174,641	$36,600	$62,800	$1,258	20	3.86	2.55	4.38	2.85	4.94	3.18
	Large Single-acting Reciprocating System (> 200 hp)	162,586	167,464	$35,000	$60,200	$1,206	20	3.85	2.54	4.38	2.85	4.94	3.18
Conveyor Systems	Efficient Belt Conveyor System	3,130	3,224	$90	$150	$1	20	0.44	0.27	0.50	0.32	0.58	0.36
(Drive System, Type of Conveyance, low-friction idlers, improved layout, computer control).	Efficiency Screw Conveyor System	3,066	3,158	$110	$290	$6	20	0.99	0.49	1.13	0.54	1.27	0.60
	Efficient Apron Conveyor System	2,842	2,927	$100	$270	$5	20	0.97	0.47	1.11	0.52	1.25	0.57
	Efficient Chain Conveyor System	2,938	3,026	$120	$350	$4	20	1.14	0.48	1.31	0.54	1.49	0.60

Exhibit 4.2 (continued)

Systems and End Uses	Efficient Measures	Savings per System		Costs per System ($)			Life Years	CCEs (¢/kWh)					
		Annual kWh without line losses	Annual kWh with line losses	Incremental Cost	Full Cost	Incremental O&M		D.R = 6.00%		D.R = 8.00%		D.R = 10.0%	
								Full	Incr.	Full	Incr.	Full	Incr.
Refrigeration and Cooling	Enhanced Control—Level 1	227,760	234,593	$5,694	$17,082	$0	10	0.99	0.33	1.09	0.36	1.19	0.40
(Compressor Efficiency, Control, Refrigeration System End-use Efficiency Enclosure	Enhanced Control—Level 2	569,400	586,482	$42,705	$85,410	$2,500	15	1.93	1.18	2.13	0.43	2.34	1.38
	High-efficiency Refrigeration System	1,138,800	1,172,964	$113,880	$455,520	$2,500	20	3.60	1.06	4.17	1.20	4.77	1.35
Motors	Standard Induction to Premium Efficient Induction—Size 1 to 5 hp (Replacement)[26]	843	868	N/A	$270	N/A	20	2.71	N/A	3.17	N/A	3.65	N/A
(Standard Motors to Premium Efficiency, High-efficiency Motors to Premium Efficiency)	High-efficient Induction to Premium-efficient Induction—Size 1 to 5 hp (Purchase Option)	216	222	$30	$300	$0	20	11.78	1.18	13.76	1.38	15.86	1.59
	Standard Induction to High-efficient Induction—Size 6 to 25 hp (Replacement)	2,425	2,498	N/A	$1,100	N/A	20	3.84	N/A	4.49	N/A	5.17	N/A
	High-efficient Induction to Premium-efficient Induction—Size 6 to 25 hp (Purchase Option)	1,532	1,578	$160.0	$1,260.0	$0	20	6.96	0.88	8.13	1.03	9.38	1.19
	Standard Induction to High-efficient Induction—Size 26 to 100 hp (Replacement)	2,853	2,939	N/A	$4,200.0	N/A	20	12.46	N/A	14.56	N/A	16.79	N/A
	High-efficient Induction to Premium-efficient Induction—Size 26 to 100 hp (Purchase Option)	5,187	5,343	$500.0	$4,700.0	$0	20	7.67	0.82	8.96	0.95	10.33	1.10
	Standard Induction to High-efficient Induction—Size 101 to 200 hp (Replacement)	3,777	3,890	N/A	$8,100.0	N/A	20	18.15	N/A	21.21	N/A	24.46	N/A
	High-efficient Induction to Premium-efficient Induction—Size 101 to 200 hp (Purchase Option)	12,589	12,967	$1,000.0	$9,100.0	$0	20	6.12	0.67	7.15	0.79	8.24	0.91
	Standard Induction to High-efficient Induction—Size 201 to 500 hp (Replacement)	17,591	18,119	N/A	$22,520.0	N/A	20	10.84	N/A	12.66	N/A	14.60	N/A
	High-efficient Induction to Premium-efficient Induction—Size 201 to 500 hp (Purchase Option)	17,591	18,119	$2,520.0	$23,520.0	$0	20	11.32	1.21	13.22	1.42	15.25	1.63
	Standard Induction to High-efficient Induction—Size >500 hp (Replacement)	20,912	21,539	N/A	$85,000.0	N/A	20	34.41	0.00	40.19	0.00	46.35	0.00

[26] N/A means that the incremental cost difference between standard and high efficiency is not applicable because provincial legislation requires burned out motors to be replaced by high-efficiency motors. However, full cost is still applicable because it involves replacing standard-efficiency motors prior to their end of life.

Exhibit 4.2 (continued)

Systems and End Uses	Efficient Measures	Savings per System		Costs per System ($)			Life Years	CCEs (¢/kWh)					
		Annual kWh without line losses	Annual kWh with line losses	Incremental Cost	Full Cost	Incremental O&M		D.R = 6.00%		D.R = 8.00%		D.R = 10.0%	
								Full	Incr.	Full	Incr.	Full	Incr.
Lighting	Metal-halide to T8s and Improved Control	1,051	1,083	$126	$210	$0	10	2.64	1.58	2.89	1.74	3.16	1.90
(Control, Efficient Lighting)	Metal-halide to Metal Pulse-start	701	722	$10	$330	$0	10	6.21	0.19	6.81	0.21	7.44	0.23
	Light-emitting diode (LED) Exit Lights	189	195	$15	$45	($25)	10	-9.69	-11.78	-9.39	-11.68	-9.07	-11.58
	Rewiring and Improved Control	219,000	225,570	$13,140	$61,320	$0	10	3.69	0.79	4.05	0.87	4.42	0.95
	Conversion to T-12s to T-8s	102	105	$10	$26	$0	10	3.34	1.29	3.67	1.42	4.01	1.55

4.4 TECHNOLOGY DESCRIPTIONS

This section provides further detail on the efficiency upgrades identified for each of the major industrial sector end uses. For each end use, the discussion:

- Briefly describes the energy services provided
- Identifies the baseline technology (or technologies) and/or practices
- Identifies the applicable energy efficiency upgrade options
- Provides performance and cost data for both baseline and upgrade technologies
- Calculates the Cost of Conserved Energy associated with each upgrade option.

4.4.1 Pump Systems

A pump displaces liquid along a piping system, which consists of a number of components, including motor, pump or impeller, speed control device, pipe and valve or throttle. Exhibit 4.3 illustrates the energy balance of three different pump configurations. It shows that a significant portion of the energy loss is associated with two components—the pump itself and the throttle.

Research and development in the area of pump technology focus on:

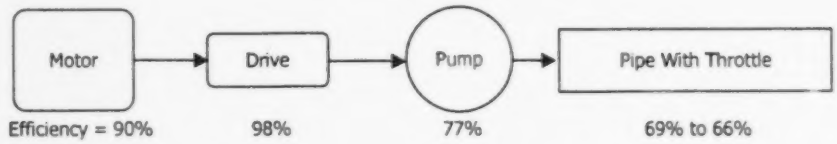
- Improving impeller design to reduce friction losses
- Improving material composition of the pumps to extend equipment life and reduce leakage.

The use of Adjustable Speed Drives (ASDs) in pumping systems is already well established for numerous industrial applications that involve the pumping of abrasive or corrosive materials. In such systems, the maintenance of control valves has proven costly, and ASDs are already used extensively to avoid the use of valves in new installations. However, audit information indicates that many existing pumping systems are valve-controlled and that there is no intention to convert them to ASD operation. Consequently, the potential savings from ASD applications on existing systems is extensive.

Computer systems are increasingly used to control entire processes, and ASDs are easier to incorporate into these systems than are conventional valve control systems. In that context, the energy saving characteristic of ASDs are only a secondary cost effect at the moment. However, as energy costs increase and those for ASD installation decrease, energy savings will provide the dominant benefit.

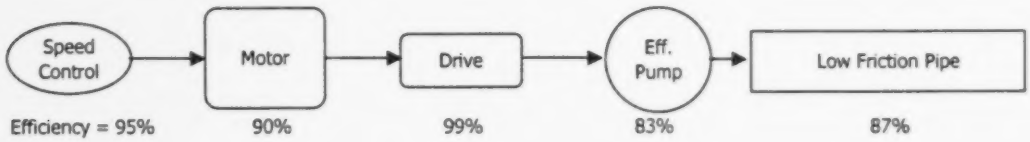
Exhibit 4.3: Illustrative Mechanical System Efficiency Improvements

Energy Input = 100 units



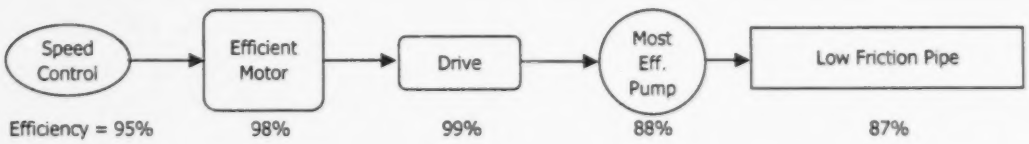
Work Output = 45 units

Energy Input = 74 units



Work Output = 45 units

Energy Input = 64 units



Work Output = 45 units

Source: Fickett et al, *in Electricity Conservation Potential Review 1988-2010: The Industrial Sector*. Volume 1. Prepared for BC Hydro, 1993.

The efficiency measures considered for this end use are summarized in Exhibit 4.4.

Exhibit 4.4: Pump System Efficiency Measures

Measure	Description
Drive System	For pumps with V-belt drives, synchronous belts
Control Method	The use of ASDs, elimination of bypass loops and other unnecessary flows, and, in some cases, trim impellers
Distribution System	Increased piping diameter to reduce friction and use of holding tanks to equalize flows over production cycle
Pump	Use of more efficient pumps
Pump System End-use Efficiency	Reduction of "safety margins" in design system capacity and implementation of water conservation projects

4.4.2 Air Displacement Systems

Air displacement (fan) systems are major electricity consumers in the Industrial Sector. Fan systems typically consist of a speed control device (although not always), motor, fan, control vane or damper and duct system. Opportunities for efficiency improvements usually exist through fan system optimization for each of these components.

Fans are used to propel a gas. Fan system curves (a graphic representation of a fan system's efficiency performance) usually show the highest efficiency lying in a narrow range of operating conditions. However, fans often do not operate in this high-efficiency range for two reasons. First, it is usually impractical to size the fan to match the load duty exactly. The pressure drop that a fan will have to work against is subject to many variables: condition of duct surface, temperature of gas and unforeseen obstructions or system additions. Therefore, as a matter of design practice, engineers will oversize fans which, in normal operation, are constantly throttled. Second, fan systems are usually required to deliver varying flow levels and, when operating below full service levels, they are throttled. ASDs, as an alternative to the throttling or damper technique, control fan systems more efficiently and offer significant conservation potential.

Fans are generally classified as one of two types: centrifugal or axial. Centrifugal fans usually generate high pressure at low speed. They are enclosed in housing and force air through a duct. The fan looks like a water wheel, where the gas is fed in through the axis of the fan and is expelled from the impeller tips.

Three types of centrifugal fans have been represented in ISTUM: Backward Inclined (BI), Radial and Airfoil. The names refer to the orientation or design of the impellers. Each fan type has a different efficiency. Although they are generally interchangeable, fans are designed for different end uses. For example, radial fans are used advantageously in dirty environments with the gas being moved containing large amounts of debris, as in the wood products industry, where there is a large amount of airborne sawdust.

Centrifugal fan applications involve process-related end uses, such as kiln ventilation, whereas axial fans are used for general ventilation or in heating, ventilation, and air conditioning (HVAC) systems. Axial fans are low-pressure, high-speed fans with a

design similar to that of the jet engine. The fan sucks air through an intake and passes it over the length of the fan before expelling it.

Axial fans fall into three categories: vane-axial, tube-axial and propeller. However, the propeller fan has no significant industrial market share. The other two fans have similar efficiencies and have been aggregated as one (called vane-axial).

Fan efficiencies are a function of their operating conditions as well as inherent engineering efficiencies. In order to determine the efficiency potential represented by matching air displacement systems more precisely to operating conditions, primary data collection would be required.

Fan blowing systems are used as a means of conveying a product such as wood chips, and the efficiency of these systems can be improved in the same way as for fan systems. Thus, the savings potential of improving blowing systems is included in the air displacement category. It should be noted that substantial energy savings could also be achieved by moving from a pneumatic to a belt type of system. However, based on the previous experience of Willis Energy, it has been found that such conversions are usually very expensive and generally not economic. Consequently, the conservation potential of this measure has not been estimated.

The efficiency measures considered for this end use are summarized in Exhibit 4.5.

Exhibit 4.5: Air Displacement System Efficiency Measures

Measure	Description
Drive System	For fans with V-belts, savings potential with synchronous belts
Control Method	Use of ASDs to adjust motor drive, throttle, reduction of speed by smaller sheave size and computer turn-off of exhaust fans during down periods
Distribution System	Reduction of duct losses through vanes that turn at elbows, reduced obstructions in flow paths and re-routing of ducting
Fan System End-use Efficiency	Reduction of fan oversizing and of over-air supply (i.e. over-ventilation, high levels of excess air in combustion processes)

4.4.3 Compressed Air Systems

A compressor is designed to increase the pressure of a gas to a useful level. Typically, air is compressed from atmospheric (15 psig) to 100 psig (pounds per square inch—gauge pressure), which is the most common operating pressure used in industry. Compression systems consist of a compressor, pipe system, dryer/filter unit, throttle or vane, and motor. A motor could have an ASD or the configuration may include a speed control device.

Compressor systems are the least efficient of the auxiliary systems, and they average between 15% and 20% total system efficiency. The inefficiency is due to the nature of a gas, which absorbs energy as it is compressed. The absorbed energy is lost as heat.

Compressors are similar to pumps in design. The following four types are common: centrifugal, rotary screw, single-acting (stage) reciprocating and double-acting reciprocating.

Reciprocating compressors are generally smaller than other types of compressors (less than 200 hp), and they provide more precise gas pressure. Double-acting compressors dominate the reciprocating compressor market because of their reliability and higher efficiency in comparison to single-acting compressors. Reciprocating compressors are more expensive than centrifugal and rotary compressors, but they maintain a small part of the compressor market because of their ability to provide constant exit gas pressure.

Rotary screw compressors, which are reliable and cheap, dominate the market. Though they are less efficient than centrifugal compressors, the difference is small. Rotary screw compressors can be operated in dirty and corrosive environments, which gives them more flexibility than centrifugal compressors in industrial applications.

Centrifugal compressors, which are similar to centrifugal fans and pumps in design, are the most-efficient type of compressor, but they are more limited in application than the rotary screw.

The efficiency measures considered for this end use are summarized in Exhibit 4.6.

Exhibit 4.6: Compressed Air System Efficiency Measures

Measure	Description
Drive System	For compressors with V-belt drives, savings potential with synchronous belts
Control Method	Use of adjustable speed drive, replacement of inlet throttling with load-unload control, installation of flow controllers, use of sequencers to control multi-compressor systems
Distribution and Storage	Increased piping size and re-routing to reduce pressure drop and, in some cases, breaking of large system into smaller systems, increase of receiver size and installation of additional storage at a number of locations in system, improved maintenance of inlet filters and use of more efficient air dryers
Compressors	Use of more-efficient compressors
Compressed Air End Use	Implementation of leakage control program, replace use of compressed air with blowers where appropriate, use of efficient nozzles for cleaning application, and reduction of system over-pressure

4.4.4 Material Conveyance Systems

A conveyance system is a horizontal or inclined device for moving bulk material. The system, which is much simpler than that of a pump or air-displacement system, consists of a belt or pulley assembly (a conveyor), a speed control device (some are direct drive) and a motor. Design considerations depend on the specific operating conditions and the experience of the designer.

Conveyance systems account for a small portion of industrial demand for electricity, typically less than 5%. The simple nature of conveyance systems means that the potential for increased electrical efficiency is small compared to that of other systems. System efficiency is determined by multiplying the component efficiencies together.

Four main types of conveyors exist: belt, apron, chain and screw. Each serves its own market niche. The belt conveyor is widely used in industry. It can be set up to transport material several kilometres and can handle thousands of tonnes per hour. In mining, for example, belt conveyors, similar to moving sidewalks in airports, transport raw material from the mine site to the mill.

The apron conveyor is similar to the belt conveyor, except that the sides are extended upward from the conveyor bottom to retain fine-grained material. Apron and belt conveyors are often interchangeable.

Chain conveyors are commonly used in the wood products industry, where chains transport logs along a production line.

Screw conveyors are generally smaller capacity, typically less than 500 cubic metres per hour. In the pulp and paper industry, for example, the screw conveyor is used to transport wood chips, typically over short distances.

Conveyors are the most efficient of the four auxiliary systems with inherent engineering efficiencies that range from 89% to 98%. Efficiency improvements in conveyor systems involve improving the efficiency of the speed reducing gear drives, by using idlers with less friction loss, by improved design and layout and by improved computer control which shuts down conveyor systems when not needed.[27]

Conveyor efficiency depends on operating conditions, and proper maintenance is essential. It is recognized as a mature technology, with little improvement in efficiency expected over the next 20 years.

The efficiency measures considered for this end use are summarized in Exhibit 4.7.

[27] It should not be assumed that all conveyors have a mechanical control device; some conveyors operate at constant speed.

Exhibit 4.7: Material Conveyance System Efficiency Measures

Measure	Description
Drive System	Replacement of worm gears with helical or other more efficient gears and improved maintenance of idlers to reduce friction
Friction Loss Reduction	Use of idlers (rollers) with less friction. Also different conveyor material has less friction
Improved Design layout	Length and height to be conveyed can often be reduced
Improved Control	The efficiency of many systems can be improved by adding control systems, which shut down conveyor systems when not in use

4.4.5 Industrial Refrigeration Systems

A significant end use, applicable, for the most part, to the "Other" industrial subsectors in this report is refrigeration. Refrigeration efficiency improvement is included in Exhibit 4.2.

The most-effective method for improving the efficiency of refrigeration systems, as with most other industrial conservation measures, involves a system approach. In considering, for example, energy saving opportunities related to a typical freezer used to store ice cream, the type of refrigeration compressor, the type of control and the amount of insulation must be taken into account, along with the way ice cream is stacked in the room and the way it is taken in and out of the freezer.

A number of energy saving measures can provide energy efficiency improvements in industrial refrigerating systems. They include the following:

- **Enhanced Computer Control**

There are a number of good reasons for using a computer control with an industrial refrigeration system, the most important being energy savings and production improvements through optimized operation of the refrigeration equipment. This method of saving energy is ranked as the most important, because it can be readily applied to retrofit applications, besides being critical to good design practice for new installations. A refrigeration control system can be divided into four categories: compressor control, condenser control, evaporator control and refrigerated area monitoring.

- **Defrost Cycling**

Evaporator coils have to be periodically defrosted to remove ice build-up. It is a process that costs energy because it involves putting heat into the refrigerated space. In many cases, defrosting is done simply by using manual controls or by timers. A more sophisticated approach would be to measure the temperature drop across the evaporator and to implement the defrost cycle only when the temperature deteriorates to a low value. This approach can achieve significant savings.

- **Temperature Monitoring**

The objective of refrigeration is to keep a product at a certain temperature. In auditing an industrial refrigeration system, the most important question is: "How do the refrigeration controls know the temperature in the refrigerated space?" If there are not enough temperature measurement sensors throughout the space, the controls will be unable to assess the temperature accurately, and too much cooling energy will be used.

- **Compressor Efficiency and Type of Refrigerant**

In the selection of a compressor, numerous options exist that balance efficiency and cost. Thus, decisions made involving type of compressor, number of stages of compression and type of refrigerant all affect energy efficiency.

- **Enclosure Insulation Thickness**

In general, the better the quality (type and thickness) of the insulation, the less heat loss and the greater the overall efficiency of the refrigeration system.

- **Doorway Openers and Protective Devices**

A substantial proportion of the electricity that powers refrigeration systems is used to cool air that passes into the refrigerated space through doorways. As forklift vehicles move large pallets in and out, these doorways are often left open for long periods. Fast opening doors, or even the use of strip curtains, can reduce losses.

- **Waste Heat Recovery**

Many freezers require some form of heat source under the slab to prevent heaving that could damage the concrete, make the floor uneven or displace the footings. Energy savings would result from using waste heat from the discharge gas to heat the slab in preference to heat from an electric source.

- **Compressor Suction Pressure**

As the compressor suction pressure increases, heat is removed from the freezer space with the expenditure of relatively less energy at the compressor motor. There are two methods for increasing suction pressure: one involves designing the suction piping and valves for a low-pressure drop; the second method involves using more-efficient air coil fins for transferring heat from the refrigerated space to the refrigerant.

- **Adjustable Speed Drive Applications**

The application of Adjustable Speed Drives (ASDs) can increase the efficiency of evaporator fans, compressors and cooling tower fans.

❑ **Lighting Design and Control**

All energy input into a refrigerated space has to be removed by the cooling system. Therefore, good lighting design is critical. For example, reducing the lighting load from 1 to 0.6 watts per square foot in a refrigerated space results in savings of more than 0.8 watts per square foot if the energy required for cooling the lighting waste heat is considered.

It was impractical in terms of this aggregate study to analyze in detail the energy conservation potential of each of the specific measures mentioned above. Accordingly, the following three different CCEs were developed for a typical 400-kW refrigeration system.

- **Enhanced Control—Level 1.** Compressor efficiency measures could be applied as a retrofit or for a new plant. It would involve application of low-cost measures such as optimization of evaporator fan cycling, optimization of defrost cycles or the introduction of simple Programmable Logic Controllers (PLC) of compressor operation.

- **Enhanced Control—Level 2.** Enhanced control could be applied as a retrofit or for a new plant through the application of a sophisticated computer control system. For example, a Distributed Control System could consist of one controller for the booster stage, one for the high-pressure stage, one for the condenser and one for each set of evaporators, along with one central computer for storing data and allowing the operator to make changes in set points and other control parameters.

- **High-efficiency Refrigeration System**. This measure, consisting of a distributed control system, a relatively high efficiency compressor, waste heat recovery, fast acting doors and high insulation levels, could be applied as a retrofit or for a new facility. However, it is likely that retrofits would be uneconomical.

4.4.6 Industrial Lighting

Lighting comprises a relatively small proportion of B.C.'s total industrial electricity consumption. However, significant conservation potential does exist. Moreover, lighting represents a larger proportion of total energy consumption in many growth industry sectors (e.g., small manufacturing) than for established industry.

Another consideration with industrial lighting is the impact of good lighting design. However, safety and productivity are critical to the successful operation of a manufacturing facility, and these depend to a degree on bright lighting. Accordingly, although for many industrial plants the lighting system could be re-designed and improved, the end result may not be lower power consumption.

A number of energy saving measures can provide energy efficiency improvements for industrial lighting. They include the following:

- **Metal-Halide to T8s and Improved Control**

Metal-halide lamps are used throughout a number of industrial facilities. However, as standard metal-halide lamps have a relatively long start-up time, the tendency is to leave them on all the time. Changing the metal-halide system in low-bay areas to T8's with improved control will allow for an optimum control cycle, which will result in energy savings.

- **Conventional Metal-Halide to Pulse-start Metal-Halide**

The latest pulse-start metal-halides have a much faster start-up time than the conventional units and are more efficient.

- **Light Emitting Diode (LED) Exit Lights**

Due to the large number of installed exit fixtures using incandescent type lights in industrial and manufacturing facilities, the potential for significant electricity savings exists though replacement with low-wattage LED lamps.

- **Rewiring and Improved Control**

The rewiring of circuits to group lamps according to operating hours would allow the lighting supply to be matched to lighting requirements without unnecessary lighting.

- **T12 to T8 Fluorescent Conversion**

Although most of the lighting in industrial plants is High Intensity Discharge (HID) lighting, associated office space still tends to use fluorescent lighting fixtures. Electricity savings would result from conversion to the more efficient T-8s.

4.4.7 Electric Motors

Although a wide variety of motor types exist, three represent the overwhelming majority of installed industrial capacity, and they have been singled out for inclusion in ISTUM. They are alternating current (AC) polyphase induction motors, alternating current synchronous motors and direct current (DC) motors.

As the technology for speed control in AC induction motor improves, these motors will compete more successfully with synchronous and DC motors in areas where they could not be used in the past. Presently, induction motor capacity dominates in the 200-hp and less range, whereas synchronous and DC motors dominate the greater than 200-hp market. Motors over 200 hp are generally custom-ordered, while those below 200 hp are purchased off-the-shelf.

Synchronous motors are designed for applications requiring constant speeds, and the opportunity for conservation of electricity is limited because of their already high efficiencies and special industrial applications. Large synchronous motors are often used in industry-specific processes (i.e., pulping processes in the pulp and paper industry and grinding mills in mining).

Two categories of DC motor systems exist: motor-generator (MG) and solid state (SS) systems. The difference between these categories lies not in the motor itself, but in the way current is provided. Motor-generator systems, which use an AC motor to run a DC generator to supply direct current, have an overall electrical efficiency of 65% and were the only option available prior to the 1960s. Newer motor systems use solid-state (SS) rectification to produce DC at an efficiency of 85%. Although efficiency significantly improves through upgrading to SS rectification, electricity savings are offset by the high capital costs of such equipment. Accordingly, there is still some potential for replacing MG DC motors with SS rectifiers or with ASD AC induction motors.

Exhibits 4.8 shows horsepower classes of motors as applied in the ISTUM model runs. Only the high- and premium-efficiency motors are available as replacement motors.

Exhibit 4.8: Motor Efficiencies, (% Full Load)

Size	Type	Horsepower (hp)	Standard Efficiency (%)	High Efficiency (%)	Premium Efficiency (%)
1	Induction	1-5	83.3	87.5	87.6
2	Induction	6–25	86.3	90.1	92.5
3	Induction	26–100	91.7	92.8	94.8
4	Induction	101–200	93.0	93.6	95.6
5	Induction	201–500	93.8	95.0	96.2
6	Induction	>500	94.0	95.0	N/A
5/6	Synchronous	>200	97.0		
5/6	DC MG	>200	65.0		
5/6	DC SS	>200	85.0		

Exhibit 4.9 presents the average capital cost per motor for each motor class shown.

Exhibit 4.9: Motor Capital Costs ($, 2002)

Size	Type	Horsepower (hp)	Standard Efficiency ($)	High Efficiency ($)	Premium Efficiency ($)
1	Induction	1–5	260	270	300
2	Induction	6–25	1,050	1,100	1,260
3	Induction	26–100	4,100	4,200	4,700
4	Induction	101–200	8,000	8,100	9,100
5	Induction	201–500	20,500	21,000	23,520
6	Induction	>500	84,000	85,000	N/A

O & M costs for all induction motors are estimated to be 4% of the capital cost of the standard motor. Synchronous and DC motor operating costs are estimated at 10% of capital costs. However, some expert opinion indicates that synchronous motors may require less maintenance than DC motors, which would result in operating costs nearer to those of induction motors.

4.4.8 Electronic Adjustable Speed Drives[28]

Electronic ASDs control speed by varying the rotating speed of the induction motor to match adjustable speed requirements of driven equipment. Pumps and fans are often required to deliver varying quantities of fluid flow: for example, a pump may be used to deliver 300 gallons per minute of water for a certain period, then used to deliver only half that flow rate at another time. An induction motor operates at a constant speed, and a valve or damper is conventionally used to reduce pump or fan flow. The pump or fan, when throttled, continues to use almost the same amount of electricity as in the full-load condition. Thus, in part-load conditions, energy is wasted. ASDs allow the speed of the induction motor itself to vary in order to reduce flow, with the result that energy consumption of the fan or pump is dramatically reduced during part-load operation. Therefore, in motor systems that require varying load conditions, ASDs usually offer a substantial conservation potential.

Pumps and fans are often oversized in industrial applications because the actual load conditions cannot be estimated accurately, and firms want to avoid the problems inherent with undersized equipment. In such situations, motor systems operating at constant load will be in a permanent part-load condition. For example, a pump that is operating at a constant load but is 25% oversized will be operating continuously at 80% part load. In these types of situations ASDs can save energy.

ASD updating of a system will provide flexibility to handle irregularities and will deliver different energy savings, depending on the variability of the load. Generally, the improvement in system efficiency falls into the 20% to 30% range. However, ASDs have not significantly penetrated the industrial market for two reasons: capital cost and technical problems. ASDs are twice to five-times more expensive than the motors themselves and, in some instances, they generate electromagnetic harmonics that interfere with the operation of other nearby electricity-consuming technologies.

Theoretically, an ASD can be affixed to any motor. However, based on consultations with engineers and plant managers, it is estimated that electronic ASDs can be practically applied to about half of all motor applications.

[28] The CCEs shown previously in Exhibit 4.2 are developed on a "systems basis" and are inclusive of the drive system, speed control method (e.g. ASD), distribution system and the end-use appliance (e.g., pump or fan). CCEs for ASDs, alone, were not developed.

4.4.9 Process Improvement Savings[29]

A large number of manufacturing processes use electricity in the industrial sector. Normally, the equipment for these processes is selected based on consideration of production efficiency, product quality or efficient use of raw materials. However, in analyzing the equipment options for the Pulp and Paper and Mining sectors, each has processes requiring sufficient electrical use intensity to warrant the use of electricity cost as a selection criterion.

- **Pulp Refining—Pulp and Paper**

The opportunity for improved energy efficiency in mechanical pulping is significant. Of machine drive input, only about 15% is used to actually separate the fibres of the wood chips. The rest is lost as heat (friction losses), or produces steam. Technology improvement has focused on refiner faces designed to move the fibre through the faces with less friction and reduce refiner energy requirements.

In the Economic Case, ISTUM's treatment of improved refining replaces installed conical refining with disc refining. However, given the diversity of the BC mills, the size of the required investment, and the impact on the operations of an actual mill, it is not possible to discuss project and measure costs and impact in detail in this study.

- **Extraction, Crushing and Fine Grinding—Metal Mining**

Extraction, rock crushing, and fine grinding are processes in ISTUM that rely on machine drive and motors. The savings in the economic case result from efficient motor replacement over the study period.

4.4.10 Electrolysis

The process savings shown by ISTUM in the Chemical Products subsector have been derived from the replacement of the caustic/chlorine electrolysis using a mercury cell with sodium chlorate electrolysis using a metal anode. Although the savings are included in the Economic Case for the total sector, costing and specifying replacement benefits for specific plants and projects is not possible in this study.

[29] Due to the number and complexity of the major industrial processes, it is not practical to generate individual CCE estimates for each. Instead, the study relied on the capabilities of ISTUM to select which existing process systems would be replaced by more-efficient systems over the study period. The ISTUM replacement decisions are based on lifecycle costing, which for the Economic Potential Forecast were set to approximate the avoided cost threshold of $0.06/kWh (*see* Section 5.2). (For a full listing of the process equipment selections considered by ISTUM, *see* Appendix A.)

5. ECONOMIC POTENTIAL FORECAST

5.1 INTRODUCTION

This section presents the Industrial Sector Economic Potential Forecast for the study period (FYs 2000/01 to 2015/16). The Economic Potential Forecast estimates the level of electricity consumption that would occur if all equipment and industrial building envelopes were upgraded to the level that is cost effective against the long-run avoided cost of electricity in the BC Hydro service area. In this study, "cost effective" means that the technology upgrade cost (referred to as the Cost of Conserved Energy[30], or CCE, in Section 4), is equal to, or less than, the avoided cost of new electricity supply delivered to the Lower Mainland, which is $0.06/kWh.[31]

The discussion in this section is organized according to the following subsections:

- Avoided Cost Used for Screening
- Major Modelling Tasks
- Technologies Included in Economic Potential Forecast
- Presentation of Results
- Interpretation of Results.

5.2 AVOIDED COST USED FOR SCREENING

BC Hydro Energy Planning recommended that the Conservation Potential Review team use a "levelized" cost of $0.06/kWh to assess which measures to promote customer efficiency (Demand-Side Management or DSM measures) are economic. When the 1991/94 Review was conducted, the avoided cost—or long-run marginal cost—was based on the cost of new large hydroelectric facilities. Today, planners expect the long-run marginal cost to be based on the cost of new, efficient, gas-fired Combined Cycle Gas Turbines (CCGT). The cost of CCGT supply per unit of electricity is significantly determined by the long-run marginal cost of natural gas. Current estimates are that the cost of new CCGT supply, is $0.055/kWh at the Lower Mainland load centre. However, $0.06/kWh was recommended for use in the CPR 2002 to allow a slightly more liberal screening of DSM measures for further assessment. BC Hydro does not consider the costs associated with a particular project, designed to meet specific needs, to be useful in screening categories of possible DSM measures in this Review. Using $0.06/kWh gives BC Hydro's Power Smart program planners a more robust set of data to work with as they go through the process of bundling measures into Power Smart programs. Using $0.06/kWh also ensures that the results of this study have a good "shelf life" for Power Smart program and resource planning purposes.

The Economic Potential Forecast incorporates all the electric energy-efficient upgrades that the technology assessment found with a CCE equal to or less than $0.06/kWh. The BC Hydro Core Group then reviewed the CCE results to ensure that no technology of consequence was being excluded by the six cents cut-off. They found no significant technologies had been excluded.

[30] At a discount rate of 8%.
[31] Value provided by BC Hydro.

5.3 MAJOR MODELLING TASKS

By comparing the results of the Industrial Sector Economic Potential Forecast with the Reference Case, it is possible to determine the aggregate level of potential electricity savings within the Industrial Sector and to identify specific subsectors and end uses that provide the most significant opportunities for savings. To develop the Industrial Sector Economic Potential Forecast, the following tasks were undertaken:

- The CCEs[32] for each of the energy efficiency upgrades presented in Exhibit 4.2 were reviewed, using an 8% discount rate
- Industrial equipment and process upgrades (technologies) that met the economic threshold of $0.06/kWh were "installed" within the ISTUM model using the "Winner Take All" (Economic) parameter, which mandates the replacement of existing stock with economic upgrades as soon as it is economic to do so. The model offers three opportunities for "installation" of the more-efficient technologies: (i) when existing stock is retired because of age; (ii) when existing stock is retrofitted to improve productivity, increase energy efficiency or improve reliability; and, (iii) when stock is changed to meet demand for new industrial products.

5.4 TECHNOLOGIES INCLUDED IN ECONOMIC POTENTIAL

Exhibit 5.1 lists the efficient equipment and process improvements selected for inclusion in this economic case. In each case, the exhibit shows:

- Energy end use
- Upgrade option(s) selected and "installed" by ISTUM
- Brief explanation.

Exhibit 5.1: Technologies Included in Economic Potential Case

End Use	Energy-saving Measures	Explanation
Pump System	Drive System	For pumps with V-belt drives, savings potential with synchronous belts
	Control Method	Use of ASDs, elimination of bypass loops and other unnecessary flows and, in some cases trim impellers
	Distribution System	Increased piping diameter to reduce friction, equalization of flows over production cycle using holding tanks
	Pump	Use more efficient pumps
	Pump System End-use Efficiency	Reduced "safety margins" in design system capacity, implementation of water conservation projects

[32] The term CCE that is used in this study refers to the same methodology as was used in the original CPR. However, in the original CPR, the term Total Resource Cost (TRC) was used. In both CPRs program and administrative costs were excluded. Since the TRC normally includes program and administrative costs, it was considered clearer to use the term Cost of Conserved Energy in this effort. Adding 0.5 to 1.0 cent per kilowatt hour to the CCE used in this review would give a rough approximation of the TRC as it is usually calculated.

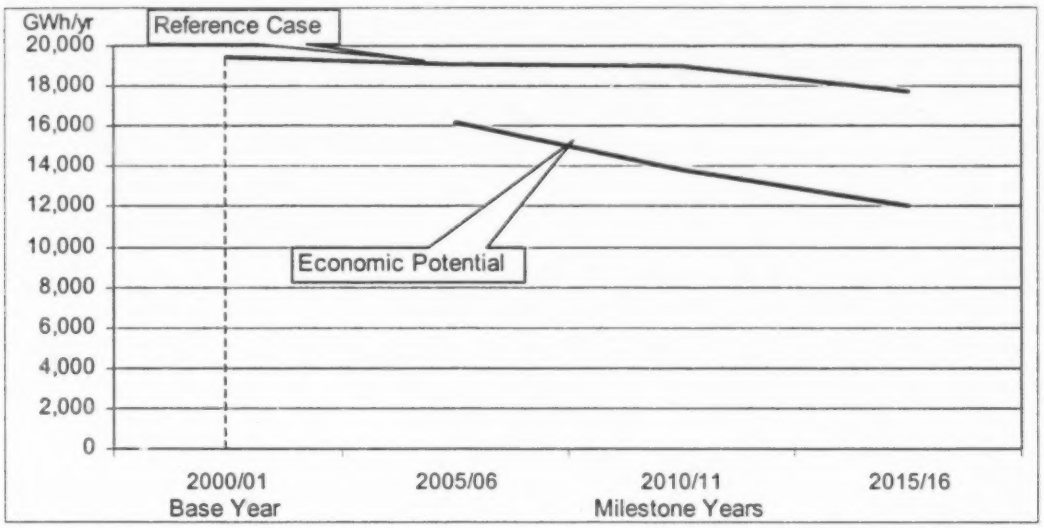
Exhibit 5.1 (continued)

Air Displacement Systems	Drive System	For fans with V-belts, savings potential with synchronous belts
	Control Method	Use of ASDs, reduction of speed by reducing shive size, computer turn-off of exhaust fans during down periods
	Distribution System	Reduced duct losses through turning vanes at elbows and reduction of obstructions in flow paths, rerouting of ducting
	Fan System End-use Efficiency	Reduced fan oversizing, reduced over-air supply situations (i.e., over-ventilation, high excess air in combustion processes)
Compressed Air Systems	Drive System	For compressors with V-belt drives, savings potential with synchronous belts
	Control Method	Replacement of inlet throttling with load-unload control, installation of flow controllers and use of sequencers to control multi-compressor systems
	Distribution and Storage	Increased piping size, rerouting to reduce pressure drop and, in some cases, breaking of large system into smaller systems, increased receiver size, installation of additional storage in various locations, improved maintenance of inlet filters and use of more efficient air dryers
	Compressors	Use of more-efficient compressors, installation of ASDs
	Compressed Air End-use	Reduced use of compressed air through use of blowers, where appropriate, use of efficient nozzles for cleaning application and reduced system over-pressure
Conveyance or Material Handling	Drive System	Replacement of worm gears with helical or other more-efficient gear, idlers belt material with less friction
	Improved Control	Efficiency improvement due to adding control systems, which shut down conveyor systems when not in use
Refrigeration and Cooling	Enhanced Control—Level 1	Application of low-cost measures, optimization of evaporator fan cycling, optimization of defrost cycles and installation of simple Programmable Logic Controllers (PLC) for compressor operation
	Enhanced Control—Level 2	Application of sophisticated computer control system to control stages of compression, evaporator fans, cooling tower fans and set points
	High-efficiency Refrigeration System	Installation of sophisticated control system, a relatively efficient compressor, waste heat recovery, fast acting doors and highly insulated enclosure
Electric Motors	At time of replacement of standard motors convert to premium-efficiency motors rather than high efficiency	Legislated standards that require standard motors, at time of replacement, to be replaced by high-efficiency motors
	At time of replacement of high-efficiency, convert to premium-efficiency rather than high-efficiency	Legislated standards that require standard motors, at time of replacement, to be replaced by high-efficiency motors
Lighting	Rewiring and Control	Use of occupancy sensors, installation of building management systems, installation of photocells and in some cases rewiring to allow portion of building lighting to be shutdown during off hours
	Efficiency Lighting	In associated office space conversion of T12 to T8, redesign of lighting systems, metal halide to Metal Halide Pulse starts
Process Savings	The ISTUM model includes the major processes used by industry in B.C. The model runs selected equipment according to specified technology and energy costs	

5.5 PRESENTATION OF ISTUM RESULTS

Exhibit 5.2 compares the industrial electricity consumption results from the Reference Case to those in the Economic Potential Case. As illustrated, under the Reference Case, industrial electricity use would decrease from the Base Year level of 19,440 GWh/yr. to approximately 17,742 GWh/yr. by FY 2015/16. This contrasts with the Economic Potential Case in which electricity use would decrease further, to approximately 12,077 GWh/yr. by 2015/16 for a reduction of 5,665 GWh/yr.

Exhibit 5.2: Reference Case versus Economic Potential Forecast—Electricity Consumption for the Industrial Sector, (GWh/yr.)



5.5.1 Electricity Savings

The following exhibits present additional detail on the potential electricity savings provided by the Economic Potential Forecast:

- Exhibit 5.3 presents the results by service region and milestone year
- Exhibit 5.4 presents the results by subsector and milestone year
- Exhibit 5.5 presents the results by energy service and milestone year
- Exhibit 5.6 presents the savings by energy service and subsector for 2005/06
- Exhibit 5.7 presents the results by energy service and subsector for 2010/11
- Exhibit 5.8 presents the results by energy service and subsector for 2015/16.

Exhibit 5.3: Total Economic Electricity Savings by Service Region and Milestone Year, (GWh/yr.)*

Milestone Year	Lower Mainland	Vancouver Island	Interior	Total	Percent Savings Re: Reference Case %
2005/2006	712	880	1,320	2,912	15.2
2010/2011	1,213	1,419	2,470	5,102	26.9
2015/2016	1,414	1,647	2,604	5,665	31.9
Percent Savings 2015/16 Re: Reference Case	30.8%	37.9%	29.6%	31.9%	

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 5.4: Total Economic Electricity Savings by Subsector and Milestone Year, (GWh/yr.)*

Subsector	Milestone Year			Percent Savings 2015/16	
	2005/06	2010/11	2015/16	Re: Ref Case %	Re: Total %
Pulp and Paper	1,978	3,246	3,769	55.3	66.5
Mines – Metal & Coal	381	760	655	28.9	11.6
Wood Products	135	242	222	8.7	3.9
Chemical and Chemical Products	263	520	600	23.5	10.6
Petroleum Refineries	52	160	194	45.1	3.4
Other	0	174	225	7.2	4.0
Total	**2,809**	**5,102**	**5,665**	**31.9**	**100.0**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 5.5: Total Economic Electricity Savings by Energy Service and Milestone Year, (GWh/yr.)*

Service	Milestone Year			Percent Savings 2015/16	
	2005/06	2010/11	2015/16	Re: Ref Case %	Re: Total %
Pumping Systems	900	1,929	1,991	49.4	35.1
Air Displacement Systems	131	185	276	13.3	4.9
Compression Systems	97	206	204	40.0	3.6
Conveyance	52	137	177	12.0	3.1
Process Equipment	1,093	1,786	1,975	22.2	34.9
Electrolysis	174	319	400	18.5	7.1
Process Heat	3	4	6	3.6	0.1
Light	34	65	67	16.4	1.2
Other	428	471	569	58.5	10.0
Total	**2,912**	**5,102**	**5,665**	**31.9**	**100.0**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 5.6: Total Economic Electricity Savings by Energy Service and Subsector for 2005/06, (GWh/yr.)*

Service	Subsector							
	Pulp and Paper	Mining	Wood Products	Chemicals	Petroleum Refining	Coal	Other Industry	Total
Pumping Systems	805	-25***	3	59	36	7	15	900
Air Displacement Systems	68	1	20	1	2	6	33	131
Compression Systems	22	0	43	21	2	0	9	97
Conveyance	29	-7	30	0	-2	0	2	52
Process Equipment	666	375	34	1	15	2	0	1,093
Electrolysis	N/A**	N/A	N/A	174	0	N/A	N/A	174
Process Heat	0	N/A	N/A	0	0	N/A	3	3
Light	0	11	0	7	0	3	13	34
Other	388	0	5	0	-1	8	28	428
Total	**1,978**	**355**	**135**	**263**	**52**	**26**	**103**	**2,912**

*Results are measured at the customer's point of use and do not include line losses.
** N/A—no end use; "0" —no savings.
*** *See* Section 5.6 – "Negative Energy Savings"

Exhibit 5.7: Total Economic Electricity Savings by Energy Service and Subsector for 2010/11, (GWh/yr.)*

Service	Subsector							
	Pulp and Paper	Mining	Wood Products	Chemicals	Petroleum Refining	Coal	Other Industry	Total
Pumping Systems	1,599	18	6	116	136	27	27	1,929
Air Displacement Systems	69	2	35	5	3	11	60	185
Compression Systems	45	1	80	56	5	1	18	206
Conveyance	93	-12***	46	0	6	1	3	137
Process Equipment	1,032	670	67	2	10	5	0	1,786
Electrolysis	N/A**	N/A	N/A	319	0	N/A	N/A	319
Process Heat	0	N/A	N/A	0	0	N/A	4	4
Light	0	19	1	22	0	3	20	65
Other	408	0	7	0	0	14	42	471
Total	**3,246**	**698**	**242**	**520**	**160**	**62**	**174**	**5,102**

*Results are measured at the customer's point of use and do not include line losses.
** N/A—no end use; "0" —no savings.
*** *See* Section 5.6 – "Negative Energy Savings"

Exhibit 5.8: Total Economic Electricity Savings by Energy Service and Subsector for 2015/16, (GWh/yr.)*

Service	Subsector							
	Pulp and Paper	Mining	Wood Products	Chemicals	Petroleum Refining	Coal	Other Industry	Total
Pumping Systems	1,634	11	6	116	160	27	37	1,991
Air Displacement Systems	133	1	36	5	6	16	79	276
Compression Systems	45	1	71	55	7	1	24	204
Conveyance	128	-8***	36	0	15	1	5	177
Process Equipment	1,337	561	64	2	6	5	0	1,975
Electrolysis	N/A**	N/A	N/A	400	0	N/A	N/A	400
Process Heat	0	N/A	N/A	0	0	N/A	6	6
Light	0	15	1	22	0	4	25	67
Other	492	0	8	0	0	20	49	569
Total	**3,769**	**581**	**222**	**600**	**194**	**74**	**225**	**5,665**

*Results are measured at the customer's point of use and do not include line losses.
** N/A—no end use; "0" —no savings.
*** *See* Section 5.6 – "Negative Energy Savings"

5.6 INTERPRETATION OF RESULTS

Highlights of the results presented in the preceding exhibits are summarized below.

Savings by Industry Subsector

- Given that the pulp and paper subsector currently accounts for nearly half of BC Hydro's industrial customer sales, it is not surprising that this subsector also accounts for the highest proportion of identified savings. As illustrated in Exhibit 5.8, it is estimated that, by 2015/16, savings of 3,769 GWh/yr. could be achieved at the facilities of BC Hydro's pulp and paper customers. This represents two-thirds of the total estimated industrial electricity conservation potential of 5,665 GWh/yr. for that milestone year.

- The chemicals and mining subsectors (coal and metal combined) provide estimated savings of 600 and 581 GWh/yr., respectively, by 2015/16. This level of savings represents roughly 10% of the total electricity used within each of these subsectors.

- About 16,000 industrial accounts and 8,000 facilities in the "Other Industry" category together provide about 4% of total sector savings by 2015/16. BC Hydro's wood manufacturing customers provide a similar level of savings. The final subsector, petroleum refining, is projected to provide less than 200 GWh/yr. of savings by 2015/16.

Savings by Service Region

- As illustrated in Exhibit 5.3, the Interior accounts for nearly half of the identified savings potential.

Savings by Milestone Year

- Exhibit 5.3 shows that the Industrial Sector may achieve electricity savings of nearly 3,000 GWh/yr. by 2005/06. This level of savings represents a drop of 15% below the Reference Case forecast. By 2010/11, potential savings increase to 5,100 GWh/yr., or 27% less than the Reference Case consumption. The growth in savings then slows and, by 2015/16, an economic electricity savings potential of 5,665 GWh/yr. is estimated. This represents a savings of 32% relative to the Reference Case.

Savings by End Use

- As Exhibit 5.8 illustrates, changes in both pumping systems and process equipment each offer almost 2,000 GWh/yr. of savings potential by 2015/16. Combined, this 4,000 GWh/yr. of savings potential accounts for 70% of all industrial economic electricity conservation potential identified for that milestone year.

- The pumping savings reflect efficiency improvement coincident with technology improvement. Within the study period, ISTUM replaced all inefficient pumps with high-efficiency pumps.

- Improvements in electrolysis operations in the chemicals manufacturing subsector would provide 7% of the estimated 2015/16 economic electricity savings.

- Improved air displacement systems would provide 276 GWh/yr. (or 5% of the total industrial electricity savings) in 2015/16, while improvements to compressor systems would account for 204 GWh/yr. (or approximately 4%). More-efficient conveyance end uses would provide 177 GWh/yr. of savings (or 3%). Lighting would provide the smallest amount of savings at 67 GWh/yr., or just over 1% of total economic industrial electricity savings by 2015/16.

Negative Energy Savings

- ISTUM indicated that there would be some negative energy savings (i.e., increased electricity use) for pumping and conveyance systems in the mining subsector. This apparently confusing result suggests that if money is spent to purchase more efficient equipment, more electricity will be used. There is an explanation, however. In the mining sector, more efficient process equipment would involve more pumps and conveyors so that, even though improved process efficiency will result in significantly less electricity being used overall it will involve a small increase in pumping and conveyor horsepower. There is nevertheless some potential for electricity saving for pumping systems in this sector.

6. ACHIEVABLE POTENTIAL ELECTRICITY SAVINGS

6.1 INTRODUCTION

This section presents the Industrial Sector Achievable Potential electricity savings for the study period (FYs 2000/01 to 2015/16). The Achievable Potential is defined as the proportion of the savings identified in the Economic Potential Forecast that could realistically be achieved within the study period.

The remainder of this discussion is organized into the following subsections:

- Description of Achievable Potential
- Approach to the Estimation of Achievable Potential
- Results.

6.2 DESCRIPTION OF ACHIEVABLE POTENTIAL

Achievable Potential recognizes that in many instances it is difficult to induce all customers to purchase and install all the electrical efficiency technologies that meet the criteria used in the generation of the Economic Potential Forecast. For example, customer decisions to implement energy-efficient measures can be constrained by important factors such as:

- Higher first cost of efficient product(s)
- Need to recover investment costs in a short period (payback)
- Lack of product performance information
- Lack of product availability
- Investment priorities.

The rate at which customers accept and purchase energy-efficient products will be influenced by the level of financial incentives, information and other measures put in place by BC Hydro, governments and the private sector to remove barriers such as those noted above.[33]

Exhibit 6.1 presents the level of electricity consumption that is estimated in the Achievable Potential scenarios. As illustrated, the Achievable Potential scenarios are "banded" by the two forecasts presented in previous sections, namely: the Economic Potential Forecast and the Reference Case. As illustrated in Exhibit 6.1, electricity savings under Achievable Potential are typically less than in the Economic Potential Forecast. Two key considerations contribute to this outcome:

- **Savings per Participant**. The bundle of measures in the Economic Potential Forecast was selected based on BC Hydro's economic criteria, not that of the customer (which has not yet been considered). Thus, the measures included in the Economic Potential Forecast may be more aggressive than those that the customer would be willing to invest in (even with BC Hydro intervention). As a result, participant electricity savings in the Economic Potential Forecast may exceed levels contained in the Achievable Potential scenarios.

[33] Further discussion of market barriers facing energy-efficient technologies, together with possible interventions is provided in Appendix C.

- **Rate of Market Penetration**. In the Economic Potential Forecast, efficient new technologies are assumed to fully penetrate the market as soon as it is economically attractive to do so. However, the Achievable Potential recognizes that under "real world" conditions, the rate at which customers are likely to implement new technologies will be influenced by additional practical considerations and will, therefore, occur more slowly than under the assumptions employed in the Economic Potential Forecast.

Exhibit 6.1 also shows that future electricity consumption under the Reference Case is greater than in either of the two Achievable Potential forecasts. This is because the Reference Case represents a "worst-case" situation in which there are no additional BC Hydro market interventions and hence no additional electricity savings beyond those that occur naturally.

Any estimate of Achievable Potential over a 15-year period is necessarily subject to uncertainty; therefore, Exhibit 6.1 presents the achievable results as a band of possibilities, rather than a single line. For example, at the time of this study, there are a number of known external factors that could significantly influence the achievable estimates presented in this section (e.g., implications of Canada's ratification of the Kyoto Protocol, changes to U.S. federal government energy policy and regional initiatives such as the Sustainable Region Initiative). Given the preceding considerations, two Achievable Potential scenarios are presented: most likely and upper.[34]

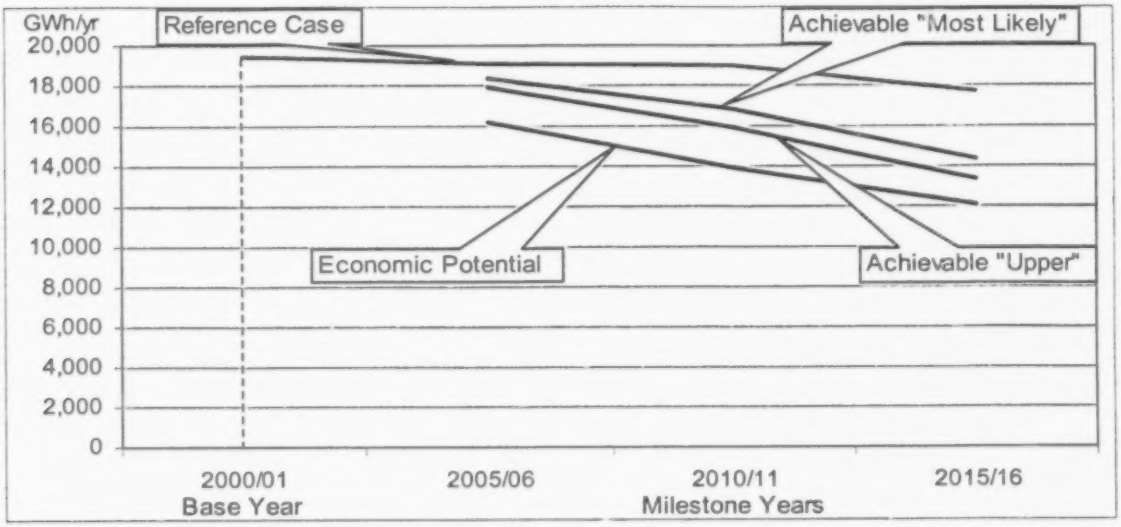
- The **most likely** Achievable Potential assumes B.C. market conditions that are similar to those contained in the Reference Case. That is, customers' awareness about energy efficiency and their motivation levels remain similar to those in the recent past, technology improvements continue at historical levels and new energy performance standards continue as per current known schedules. It also assumes that BC Hydro's ability to influence customers' decisions towards increased investments in energy efficiency remains "roughly" in line with previous Power Smart experience.

- The **upper** Achievable Potential assumes that B.C. market conditions become more supportive of energy efficiency investments. For example, this scenario assumes that the ratification of the Kyoto Protocol leads to new federal government initiatives that increase customer energy efficiency awareness and motivation. These conditions also provide additional opportunities to leverage Power Smart program resources through partnering with other organizations (e.g., the federal government). It also assumes that current U.S. federal energy policy becomes more supportive of energy efficiency. This is particularly critical to assumptions about the timing and the performance levels of upgraded appliance and equipment energy performance standards or regulations.[35]

[34] This is the upper limit of the impact of BC Hydro initiatives. It is not the estimated upper limits of electricity conservation.

[35] The estimate of customer participation rates for future Power Smart initiatives in the upper scenario assumed that there would be some increase in electricity rates charged by BC Hydro. However, there was no examination of different rate designs or the possible differential impacts of different levels of rate increases or alternative rate designs.

Exhibit 6.1: Annual Electricity Consumption—Achievable Potential Relative to Reference Case and Economic Potential Forecast for the Industrial Sector, (GWh/yr.)

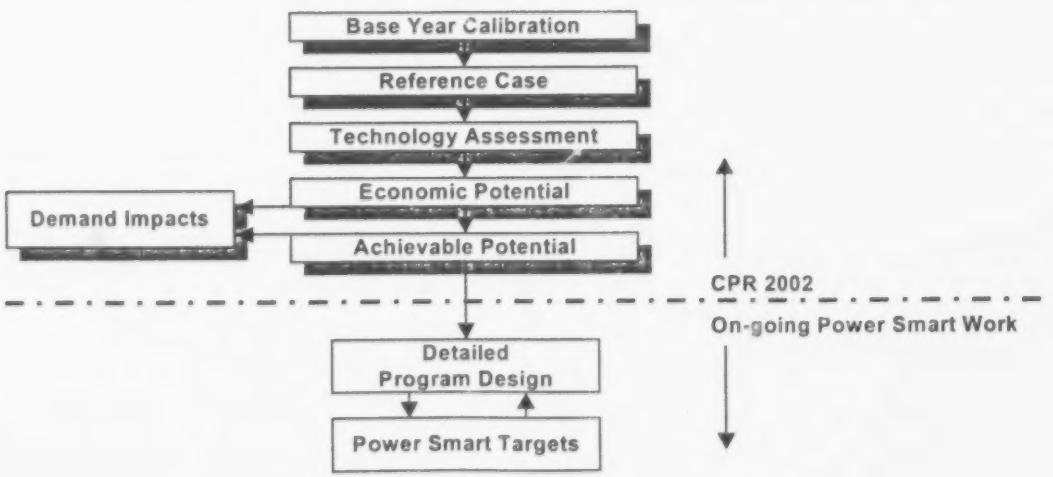


6.2.1 Achievable Potential versus Detailed Program Design

It should also be emphasized that the estimation of Achievable Potential is not synonymous with either the setting of specific Power Smart targets or with program design. Although both are closely linked to the discussion of Achievable Potential, they involve more-detailed analysis that is beyond the scope of this study.

Exhibit 6.2 illustrates the relationship between Achievable Potential and the more detailed program design.

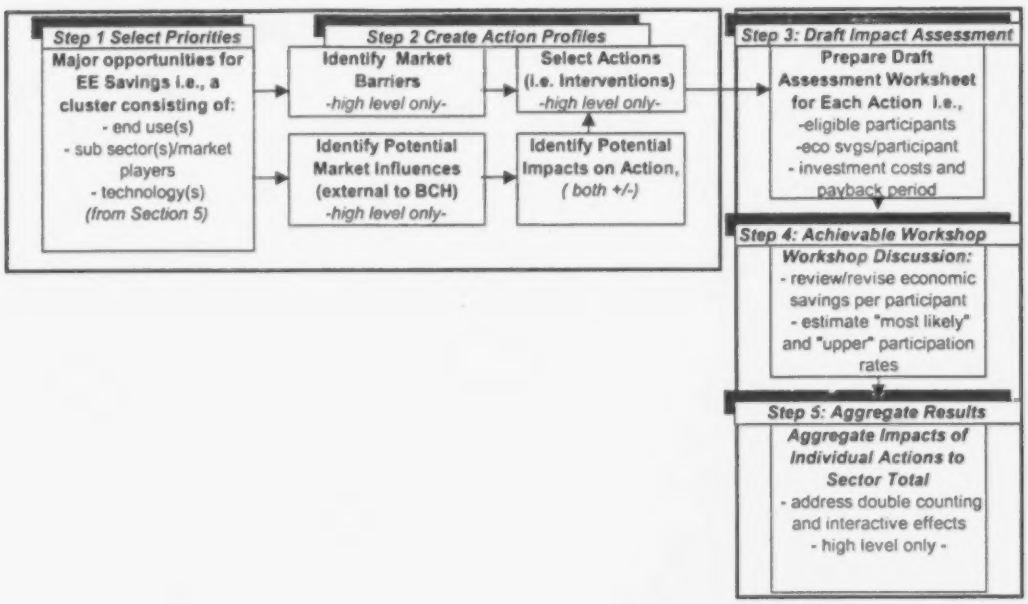
Exhibit 6.2: Achievable Potential versus Detailed Program Design



6.3 APPROACH TO THE ESTIMATION OF ACHIEVABLE POTENTIAL

Achievable Potential was estimated in a five-step approach. A schematic showing the major steps is shown in Exhibit 6.3 and each step is discussed below.

Exhibit 6.3: Flow Chart of Steps to Estimate Achievable Potential


Step 1 Select Priorities
Major opportunities for EE Savings i.e., a cluster consisting of:
- end use(s)
- sub sector(s)/market players
- technology(s)
(from Section 5)
Step 2 Create Action Profiles
Identify Market Barriers
-high level only-
Select Actions (i.e. Interventions)
-high level only-
Identify Potential Market Influences (external to BCH)
-high level only-
Identify Potential Impacts on Action,
(both +/-)
Step 3: Draft Impact Assessment
Prepare Draft Assessment Worksheet for Each Action i.e.,
-eligible participants
-eco svgs/participant
- investment costs and payback period
Step 4: Achievable Workshop
Workshop Discussion:
- review/revise economic savings per participant
- estimate "most likely" and "upper" participation rates
Step 5: Aggregate Results
Aggregate Impacts of Individual Actions to Sector Total
- address double counting and interactive effects
- high level only -

6.3.1 Step 1: Select Priorities

The first step in developing the Achievable Potential estimates required that the electricity savings opportunities identified in the Economic Potential Forecast be bundled into a set of Actions that would facilitate the subsequent assessment of their potential market penetration.

A summary of the selected Actions is provided in Exhibit 6.4. As illustrated, the Actions have been bundled by end use and, for each Action, Exhibit 6.4 shows the Action name, the target end use(s), the target subsectors and technologies, and the approximate percentage that it represents of the total industrial electricity savings contained in the Economic Potential Forecast. This percentage of the total Economic Potential is a useful guide to assessing the relative importance of the different Actions.

It should be noted that improving the efficiency of electric motors is identified as an Action. However, their energy saving potential is included within the other measures and, therefore the percentage of electricity savings achieved through motor upgrades is not itemized separately. Also note that the last item in Exhibit 6.4 is "Other," which represents 3% of the Economic Potential that has not been included in any of the Actions.

Exhibit 6.4: Industrial Sector Actions

Action #	Action Name	Target End Use(s)	Target Vintage(s)	Target Technologies	% of Total Economic Savings *(approx)*
I-1	Pump Improvement	Pumping Systems	New & Existing	• Synchronous belts • Variable speed drives • Efficient pumps • Design improvement: pipe sizing, impeller trim, application of holding tanks, capacity reduction.	35
I-2	Air Displacement Improvement	Air Displacement Systems (Incl. Pneumatic Transp. Systems)	New & Existing	• Synchronous belts • Variable speed drives • Computer controls • Design improvement: reduce fan over sizing and over ventilation.	5
I-3	Compressed Air Improvement	Compression Systems	New & Existing	• Synchronous belts • Variable speed drives • Design improvement: flow controls, sequencers, rerouting, optimizing size of systems, and add storage capability. • Efficient compressors	4
I-4	Conveyance or Material Handling Improvement	Conveyance	New & Existing	• Efficient gears, such as helical • Belt conveyors • Maintenance Improvement	3
I-5	Refrigeration and Cooling Improvement	Refrigeration	New & Existing	• Efficient compressors • Temperature measurement • Controls operation	9
I-6	Electric Motor Efficiency Improvement	All end uses except light, electrochemical	New	• Premium efficiency motors—*see* comment on motors in Section 6.3.1	
I-7	Industrial Lighting and Controls Improvement	Light	New & Existing	*General lighting* • Lighting redesign, advanced T8 and Ergolight controls—large plant offices • Lighting redesign, advanced T8—all remaining industrial *Architectural lighting* • Advanced T8, CFLs and white LED—all industrial *High bay lighting* • High intensity fluorescent—all industrial *Controls* • Timeclocks, occupancy sensor, photocell sensors	4
I-8	Mechanical Pulping Improvement	Process Equipment	New & Existing	• New thermal heat recovery technologies	8
I-9	Process Improvement	Process Equipment	New & Existing	• Control systems for ball mills	14
I-10	Steam Optimization	Process Equipment	New & Existing	• Condensing turbine, to utilize the low-pressure steam saved by heat recovery projects	11
I-11	Industrial Indoor Air Quality	Heating, Ventilating and Air Conditioning, industrial buildings	New & Existing	• Synchronous belts • Variable speed drives • Computer controls • Design improvement: reduce fan over sizing and over ventilation, conduit sizing, ensure ventilation at work sites	4
	Other	This category represents opportunities in the Economic Potential Savings that could not be categorized into one of the above Action Items.			3

6.3.2 Step 2: Create Action Profiles

The next step involved the development of brief profiles for each of the Actions noted in Exhibit 6.4. A sample profile for Pump Improvement is presented in Exhibit 6.5. (For Action Profiles for the other Actions *see* Appendix C.)

The purpose of the Action Profiles was to provide a "high-level" logic framework that would serve as a guide for participant discussions in the Achievable Workshop (*see* below). The intent was to define a broad rationale and direction without getting into the much greater detail required of program design, which, as noted previously, is beyond the scope of this project.

As illustrated in Exhibit 6.5, each Action Profile addresses the following areas:

Goal—provides a summary statement of the broad goal and rationale for the Action.

Target Technologies and Subsegments—highlights the major technologies and the subsegments where the most significant electricity savings opportunities have been identified in the Economic Potential Forecast.

Target Stakeholder Groups—identifies key market players that would be expected to participate in electricity efficiency initiatives and who would be involved in the actual delivery of services. The list of stakeholders shown is intended to be "indicative" and is by no means comprehensive.

Key Barriers and Interventions—identifies key market barriers that are currently constraining the increased penetration of the energy-efficient technologies or measures. Interventions for addressing the identified barriers are noted. Again, it is recognized that the interventions are not necessarily comprehensive; rather, their primary purpose was to help guide the workshop discussions.

Time Frame—identifies the potential timing of activities with the intent of assisting workshop participants to envision possible customer participation rates.

Relationship to Other Actions—identifies possible synergies with other Actions that may affect workshop participant views on possible customer participation rates.

Exhibit 6.5: Sample Industrial Action Profile

Action Profile I-1—Pump Improvement

Goal:

The goal of this Action is to improve overall performance and efficiency of pumping systems while reducing operating costs and extending the life of the equipment. This Action will assess pump systems for efficiency and savings, including: belts, variable speed drives, elimination of unnecessary flows, impeller trim, pipe sizing, end use efficiency and water conservation.

The achievable savings will depend on a number of the customer's business and operational factors, such as plant development strategy (shutdown or expansion), plant operation strategy to meet their markets, operational staff availability and workload to implement energy efficient initiatives.

Target Technologies and Subsegments:

- Synchronous belts
- Variable speed drives
- Efficient pumps
- Design improvement: pipe sizing, impeller trim, application of holding tanks, capacity reduction

Target Stakeholder Group:

- Pump Distributors—area sales managers, product sales managers, marketing and training managers
- Utility customers—operations managers, plant supervisors, maintenance supervisors
- Water utilities—DSM program managers, supply planners, rate managers
- Consulting engineers –design standards, service managers

Key Barriers and Interventions:

Experience to date indicates that the most significant barriers to pump system improvement are:

- lack of customer focus on energy efficiency
- customers' inability to analyze/utilize the technical information
- requirement of a shared corporate/operations vision to bring resources to the project
- resistance to change
- budget
- additional work required by staff

These Actions would address these barriers by combining the following interventions:

- Project management and coordination
- Engineering design and product application expertise
- Custom information packages for each area within customer's firm
- Incentive amounts to bring payback to within operating budget
- Evaluation reporting
- Third-party verification

Time Frame:

Start up in 2003 with pilot project; with pilot results and trade allies to develop promotional materials and identify specific projects; "purchase" projects as available/required.

Relationship to Other Actions:

It will be necessary to prioritize pump improvements in terms of customer needs and savings potential amongst other systems (air displacement, compressed air, conveyance or material handling, and refrigeration and cooling).

6.3.3 Step 3: Prepare Draft Action Assessment Worksheets

A draft Assessment Worksheet was prepared for each Action Profile in advance of the Achievable Workshop. The Assessment Worksheets complemented the information contained in the Action Profiles by providing quantitative data on the potential electricity savings for each Action as well as providing information on the size and composition of the eligible population of potential participants. Energy savings data were taken from the detailed modelling results contained in the Economic Potential Forecast. Average saving per project estimates were based on the consultant's experience with former Power Smart activity.

A sample most likely Assessment Worksheet for Action I-1 Pump Improvement is presented in Exhibit 6.6. (For worksheets on the remaining Actions *see* Appendix D.) As illustrated in Exhibit 6.6, each Action Assessment Worksheet addresses the following areas:

Economic Electricity Savings (GWh/yr.)—This is the total economically attractive electricity savings identified for this particular Action Profile.

Number of Projects—This is the estimated number of projects that are candidates for the Achievable Potential. It represents an aggregation of the individual systems and savings contained in the Economic Potential into "typical" projects that might be realistically of interest to industry.

Number Remaining after Previous DSM Activity—For the purpose of these calculations, the DSM activity is the activity initiated after 2000/2001. The first estimated savings for this Exhibit are listed in 2005/06. For years 2010/11 and 2015/16, it is necessary to take into consideration the estimated DSM savings from previous years.

% of Projects Eliminated By Constraints—These estimates reduce the number of potential projects. They recognize that in the industrial sector some business constraints that reduce conservation potential cannot be effectively addressed by DSM activities. It should be noted that constraints are different than market barriers which it is assumed can be reduced by the use of DSM activities. A market barrier, for example, such as a lack of customer focus on energy efficiency can be addressed by incentive offerings or other DSM initiatives. However, if the customer perceives that a part of his plant is going to be shutdown within 2 years there is really no DSM activity that can address that issue. Two sets of constraints were considered in this portion of the analysis as follows:

- *Customer perception of risks.* Changing market conditions may mean that portions of a facility's current operation may have a limited or uncertain future. Under these conditions, owners are unlikely to make energy conservation investments for those particular facilities or parts of facilities. This is an important consideration in estimating industrial conservation potential because often the facilities that are relatively inefficient and have a high potential for conservation are also the ones that are scheduled for closure.
- *Physical constraints.* Limited available physical space may in some cases restrict the implementation of projects that would otherwise be technically viable.

Projects Available for DSM Activity—This is an estimate of the number of projects that are suitable targets for DSM programs. The estimate is the total number of projects minus the ones already obtained from previous DSM activity and adjusted for business constraints.

Participation Rate—This is an estimate of the percentage of available projects that would be implemented within each period. This estimate takes into consideration decision time as well as engineering time required to implement efficiency measures. Two participation rates were estimated for each Action: most likely and upper. Exhibit 6.6 shows the estimated participation rate for Action I-1 (Pumps) under the most likely scenario. The upper Achievable Potential (not shown) assumes that the participation rate of "Projects available for DSM" is double the value used in the most likely scenario, up to a limit of 100%. For example, the most likely scenario for Action I-1 assumes a participation rate of 20% in the milestone period to 2005/06. In this case, the upper scenario assumes a participation rate of 40% in the same period.

Number of Projects Implemented—This item is the Participation Rate multiplied by the Projects Available for DSM Activity.

Calculated Achievable Potential (GWh/yr.) Per Period—This item is Number of Projects multiplied by the Average Savings per Project and converted from kWh to GWh/yr. by dividing by 1,000,000.

Average Savings Per Project—The conservation potential estimate was determined for the Industrial sector on an energy system basis. For example, the total electricity used by pumping systems within the sector was estimated and then the potential electricity savings were estimated for that end-use. The size of the systems involved ranges from small systems involving pumps from 5 to 100 horsepower in size to large systems involving pumps that are thousands of horsepower. The analysis in this section combines these types of systems into Projects that are more typical of industrial activity. This estimate was based extensively on previous experience with Power Smart programs and experience from other jurisdictions.

Reduction in Savings Per Project—This was used to account for the gap between the theoretical savings potential (contained in the Economic Potential forecast) and the levels that can realistically be attained in an actual project. For example, numerous actual energy projects are faced with limited flow measurement data; as a result it is often impossible to achieve fully optimized levels of energy savings.

Average Savings per Project to be used in Calculating Achievable Potential—This item is the Average Savings per Project minus the inherent Reduction in Savings per Project.

Exhibit 6.6: Sample Action Assessment Worksheet—Pulp and Paper Subsector: Most Likely Achievable Potential

Action Profile Number: **I-1**
Pumping

Year	2005/06[36]	2010/11[35]	2015/16
Economic Energy Savings (GWh/yr.)	564	1,119	1,144
Number of Projects	512	1,018	1,040
Number Remaining after Previous DSM Activity (in accumulated prior periods)	512	962	825
% of Projects Eliminated By Constraints			
1/ Customer perception of risk of installed capacity being taken out of service prior to economic replacement	35%	35%	35%
2/ Inability to physically integrate energy saving initiatives into existing operation.	10%	10%	10%
Total Percent Eliminated Due to Constraints	45%	45%	45%
Projects Available for DSM Activity	282	529	454
Participation Rate	20%	30%	30%
Number of Higher Efficiency Projects Implemented Per Period	56	159	136
Calculated Achievable Potential (GWh/yr.) Per Period	62.0	174.5	149.7

Note 1—Average Savings per Project (assumes combination of systems from Economic Potential)	1,100,000 kWh
Note 2—Reduction in Savings per System	0%
Note 3—Average Savings per Project to be used in Calculating Achievable Potential	1,100,000 kWh

[36] For this particular Action item, there is a significant increase in energy saving potential between 2005/06 and 2010/11 because the ISTUM model assumes that many pumping systems will have to be replaced during that time period.

6.3.4 Step 4: Achievable Workshop

A one-day Achievable Workshop was held on November 19, 2002. Workshop participants consisted of core members of the client and consultant team as well as key program and technical personnel from BC Hydro's industrial Power Smart programs. Together, the participating BC Hydro personnel brought to the workshop many years of experience in the design and delivery of energy-efficient programs within the BC market.

The purpose of this workshop was twofold:

- To promote discussion between the consultants and the Power Smart personnel regarding the identified electrically efficient opportunities
- To promote discussions among the BC Hydro personnel themselves related to how much of the identified economic savings could realistically be achieved over the study period.

The discussion of each Action Profile began with a brief consultant's presentation. The floor was then opened to participant discussion of the key factors affecting each of the market segments and technical opportunities contained in the Action Profile and accompanying assessment Worksheet. An important part of the discussion involved a discussion of the percentage of "Systems Eliminated by Constraints". There was general consensus that for the industrial sector it was necessary to modify the economic potential due to one of the following two reasons:

- Customer perception of risk of installed capacity being taken out of service prior to economic replacement;
- Inability to physically integrate energy saving initiatives into existing operation.

The significance of these restraints was estimated for the major energy savings areas.

As noted earlier, it was not possible to fully address all Actions in the one-day workshop. Consequently, the workshop focused on the "big ticket" Actions and follow up discussions were held with BC Hydro program personnel after the workshop. Two major saving areas were the prime focus of these follow up activities and are discussed below.

- ***Large Energy System Potential—Pulp and Paper***

Pulp and paper is the largest industrial subsector. It includes a relatively small number of large energy systems, which represent a significant portion of the total electricity saving potential for the sector. Given that the number of systems involved was relatively small, the potential savings in these systems was analyzed separately through discussions with BC Hydro Key Account representatives and BC Research, and by identifying each of the systems from published data.[37] The ISTUM calculation was then modified accordingly.

[37] It is important to note that to accurately understand the potential for each of these systems, detailed engineering studies would be required, which was beyond the scope of this study.

❑ *Mechanical Pulping Optimization*

Mechanical pulping is very electricity intensive. In recent years, there has been a trend away from chemical pulping and towards mechanical pulping and this trend is expected to continue. There are a number of reasons for this trend but one of the most important is that mechanical pulping is usually much more efficient with respect to wood fibre utilization (90% versus 60% for chemical).

The intense use of electricity in mechanical pulping is a major cost consideration. Consequently, considerable efforts are being expended by equipment manufacturers and by end users to improve the efficiency of this process. The work being done is complex and cannot be dealt with in detail within this study. However, an estimate of the electricity saving potential in this area was accomplished by listing all the mechanical pulping systems that are identified in Lockwood-Post's pulp and paper directory and then assigning an electricity saving potential to each of these systems. This analysis was then followed by discussions with BC Hydro Key Account representatives who are familiar with plans and activities in each of the facilities involved.[38].

The approach taken was to break the saving potential into the following three levels:

- Control optimization—more sophisticated control of energy and product grade (assumed 5% savings potential);
- Refiner optimization—tertiary refining and other modifications (assumed 10% savings);
- Complete refiner replacement, which would involve extensive heat recovery of the steam generated, which could be utilized to increase the amount of electricity self generated at mill sites. (Assumed 20% savings increase).

It was estimated that the first level (control optimization) could be achieved by 2005/06 because of the limited physical modifications that would be required, that the second level (refiner optimization) could be achieved by 2010/11 and the third level (refiner replacement) by 20015/16. The results of the analysis are provided in Exhibit 6.7.

Based on industry information sources,[39] the cost of conserved energy for these projects is considered to be well below the $0.06/kWh threshold. However, the economics of refiner projects varies significantly from project to project. Finally, the estimation of potential customer participation is complicated by the fact that their motivation to implement equipment improvements is often due to reasons other than energy cost reduction e.g., productivity improvement, improved product quality and reduced maintenance costs.

[38] It is important to note that actual plans for any particular facility or company are confidential and are not available for the purposes of this study.
[39] Actual costs for specific projects are not available due to confidentiality.

Exhibit 6.7: Most Likely Achievable Potential from BC Mechanical Pulp Mills in Total BC Hydro Service Area, (GWh/yr.)

	Primary*	Secondary*	Rejects*	Totals	Estimated Annual Electricity Savings (GWh/yr.) By Milestone Year		
					2005/06	2010/11	2015/16
# of Mills				9			
# of Refiners	41	32	18	91			
Total HP	476,000	413,600	158,200	1,047,800			
Total MW	355	308	118	781			
Est'd GWh/yr.	2,488	2,161	827	5,476	274	548	1095

*Wood chips are usually ground into pulp in multiple stages, beginning with the primary and secondary stages; the rejected chips from the first two stages are processed again in a reject stage.

Pulp Mill Steam Cycle Optimization[40]

Steam cycle optimization in pulp mills, which would result in the mill process generating more of its own electricity, represents another area for significant purchased electricity savings. Many mills have excess boiler and fuel-handling capacity due to previous steam conservation initiatives and process modifications that have lowered process steam requirements from the levels that existed when the boilers were initially sized. In many cases, there is also a potential for additional heat recovery projects that would further reduce the need for steam. If hog fuel (wood waste) is the dominant fuel in these situations, the installation of a steam turbine generator is likely to be an economically attractive option. The steam generator would utilize steam at 80 psig (pounds per square inch—gauge pressure) and generate electricity to be used in the process. Typically, these projects would not require the addition of boiler or fuel handling capacity.

Exhibit 6.8 presents an estimate of the Achievable Potential offered by this type of project. The estimate is based on several sources including:

- Published data contained in Lockwood-Post's directory and other published sources that identify the existing boiler capacity and steam turbine generation for B.C. pulp mills.
- Information on optimization projects that have already been implemented, such as the upgrade project at Cariboo Pulp and Paper, Abitibi-Mackenizie's 14-MW generation project, which came on line in 1997, and the generation upgrade project at the Skookumchuck Pulp mill.
- Discussions with BC Hydro Key Account representatives.

[40] Steam cycle optimization was not included in the preceding phases of this analysis as it involves fuel switching, which is technically outside the scope of this study. However, in the discussions that took place during the achievable portion of this analysis, it was acknowledged that because the fuel would be "waste" wood, this opportunity was on the margin of the study's scope. Given the potentially significant contribution of this opportunity, it was decided to include a separate discussion of this measure in the estimate of achievable potential; however, due to the study's time constraints, it was not possible to re-do the economic potential forecast to include this measure.

To obtain an accurate estimate, detailed studies would be required at each pulp mill[41]. The feasibility of these projects also depends on hog fuel availability, which could be a limiting factor in some locations.

The economics of steam optimization projects vary significantly from project to project due to the uniqueness of each steam system. However, recent project experience indicates that the cost of conserved energy for these projects is in the order of $0.05/kWh.

Exhibit 6.8: Most Likely Achievable Potential from Increased Self-generation in B.C. Pulp and Paper Mills, (GWh/yr.)

	Thermal Generation Capacity at P&P mills (Suitable Targets for Efficiency Improvement) (MW)	# of Pulp Mills With Thermal Self-generation	20% Generation Capacity [42] Increment (MW)	Additional Annual Electricity, 2015/16 (GWh/yr.)
Total BC Hydro Service Area	390	15	78	504

Notes:

1. Based on existing boiler–turbine/generator capacity.
2. Cariboo Pulp and Paper excluded since its recent upgrade formed the basis for the assumed 20% increase in output achievable with modification of existing generation equipment. This upgrade increased electricity generation output from the mill's existing turbo-generator from 31.75 MW to 37.7 MW.
3. Abitibi-Mackenzie cogeneration capacity of 14 MW is excluded because the unit was new in 1997.
4. Celgar Pulp is excluded because it is not in BC Hydro's service area.
5. 80% load factor assumed for generation operation.

There is also a potential for gas-fired cogeneration at many of these steam pulp mills; however, this option is outside the scope of this study.[43]

6.3.4 Step 5: Aggregate Action Results

The final step involved aggregating the results of the individual Actions to provide a view of the potential achievable savings for the total industrial sector.

[41] Some of these studies have been completed but are confidential.

[42] The 20% savings estimate assumes that the existing generation of pulp mills can be increased by 20%. The estimate is based on the experience at Cariboo Pulp and Paper and on Willis Energy's knowledge of generation in other B.C. mills.

[43] It should be recognized that the distinction between self-generation, efficiency improvement and load displacement is not easily defined in these mills.

6.4 RESULTS

The Achievable Potential results are presented in three exhibits.[44]

- Exhibit 6.9 provides a summary of the Achievable Savings Potential by service region and milestone year.
- Exhibit 6.10 presents a summary of the Achievable Savings Potential under the most likely and upper scenarios, by Action and milestone year.
- Exhibit 6.11 presents a summary of the Achievable Savings Potential under the most likely and upper scenarios by industrial subsector and milestone year.
- Exhibits 6.12 (most likely) and 6.13 (upper) show the estimated electricity savings in the milestone year 2015/16 for each Action in the form of supply curves that also incorporate the Cost of Conserved Energy (CCE). This view, therefore, shows the level of electricity savings that could be achieved under various investment thresholds.

Exhibit 6.9: Summary of Achievable Electricity Savings* by Service Region and Milestone Year

Service Region	Milestone Year	% of Total Savings by Region	Achievable Savings (GWh/yr.)	
			Most Likely	Upper
Total BC Hydro Service Area	Base Year			
	2005/06	100	747	1,189
	2010/11	100	2,151	3,058
	2015/16	100	3,374	4,338
Lower Mainland	Base Year			
	2005/06	25	187	297
	2010/11	24	516	734
	2015/16	25	844	1,085
Vancouver Island	Base Year			
	2005/06	30	224	357
	2010/11	28	602	856
	2015/16	29	978	1,258
Interior	Base Year			
	2005/06	45	336	535
	2010/11	48	1,032	1,468
	2015/16	46	1,552	1,995

*Results are measured at the customer's point of use and do not include line losses.

[44] Savings shown for FY 2005/06 include the impacts of new Power Smart activities implemented since the base year of FY 2000/01.

Exhibit 6.10: Summary of Cumulative Achievable Potential Electricity Savings by Action and Milestone Year, (GWh/yr.)[45]*

Action	Annual Electricity Savings by Milestone Year, (GWh/yr.)					
	2005/06		2010/11		2015/16	
	Most Likely	Upper	Most Likely	Upper	Most Likely	Upper
I-1 Pump Improvement	110.2	217.2	563.9	998.1	905.4	1415.2
I-2 Air Displacement Improvement	23.7	36.5	69.2	109.5	113.7	170.5
I-3 Compress Air Improvement	29.0	41.6	91.3	143.2	122.9	164.5
I-4 Conveyance or Material Handling	18.9	37.7	70.9	112.7	100.2	142.5
I-5 Refrigeration and Cooling Improvement	2.0	4.0	10.1	15.9	16.1	21.2
I-6 Electric Motor Efficiency Improvement	*Included in above actions*					
I-7 Industrial Lighting and Controls Improvement	24.0	48.0	113.0	186.0	162.9	236.4
I-8 Mechanical Pulping Improvement	274.0	274.0	548.0	548.0	1095.0	1095.0
I-9 Process Improvement	32.6	65.3	187.4	303.5	247.4	381.8
I-10 Steam Cycle Optimization	218.4	436.8	428.1	524.2	503.5	541.6
I-11 Industrial Indoor Air Quality	14.3	28.0	68.9	116.9	107.3	169.4
Total (rounded) BC Hydro Service Area	**747**	**1,189**	**2,151**	**3,058**	**3,374**	**4,338**

*Results are measured at the customer's point of use and do not include line losses.

Exhibit 6.11: Summary of Cumulative Achievable Potential Electricity Savings by Subsector and Milestone Year, (GWh/yr.)*

Subsector	Annual Electricity Savings by Milestone Year, (GWh/yr.)					
	2005/06		2010/11		2015/16	
	Most Likely	Upper	Most Likely	Upper	Most Likely	Upper
Pulp and Paper	606.4	938.8	1568.7	2107.6	2542.5	3157.3
Mining—Metals	43.9	87.8	217.8	364.0	291.4	448.9
Wood Products	52.7	80.2	106.2	151.6	125.4	145.9
Chemicals	19.7	39.3	110.4	195.8	162.8	230.0
Petroleum Refining	5.7	11.4	63.0	103.3	112.8	157.0
Mining—Coal	7.6	9.8	30.9	40.8	45.3	54.4
Other Industry	11.1	21.7	53.7	95.0	94.2	144.7
Total (rounded) BC Hydro Service Area	**747**	**1,189**	**2,151**	**3,058**	**3,374**	**4,338**

*Results are measured at the customer's point of use and do not include line losses.

[45] Action I-8 "Mechanical Pulping Improvement" shows the same value for most likely and upper achievable scenarios. This is because this opportunity involves a small number of sites and is seen as being very attractive to customers. Consequently, it is expected that in the most likely case, 100% of this opportunity could be captured.

Exhibit 6.12: Supply Curve of Industrial Sector Actions—Cumulative Electricity Savings in the Milestone Year of 2015/16 for Most Likely Scenario, (GWh/yr.)

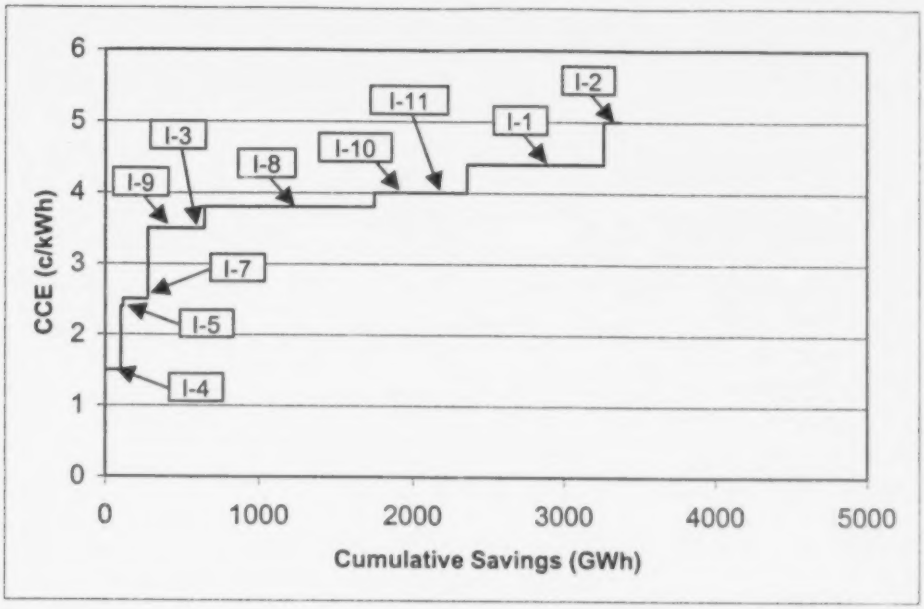
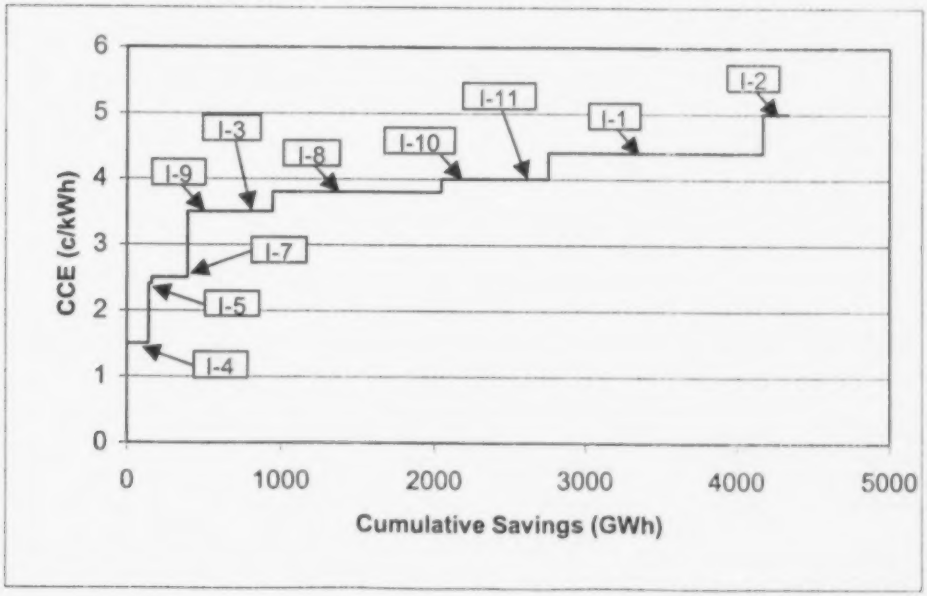


Exhibit 6.13: Supply Curve of Industrial Sector Actions—Cumulative Electricity Savings in the Milestone Year of 2015/16 for Upper Scenario, (GWh/yr.)



6.4.1 Comments on Results

The results presented in the preceding exhibits show that 74% of the most likely achievable electricity saving opportunities are in three areas:

- Mechanical pulping enhancements (32%)
- Pump system improvements (27%), and
- Steam cycle optimization (15%).

It is also important to note that the above opportunities particularly involve the pulp and paper sector and that achieving the identified potential electricity savings would require a significant amount of specialist engineering work and a significant level of capital investment. The current market conditions provide a unique opportunity for BC Hydro to work with the pulp and paper sector to improve its efficiency and competitiveness and, at the same time, to significantly reduce the amount of electricity used by this subsector.

As noted above, this study has identified significant electricity savings potential in pumping systems. This is consistent with the findings of the first conservation potential review. However, during the first phase of Power Smart program activities only a relatively small portion of the identified pumping electricity savings were captured and, consequently, a large potential savings continues to exist in pumping systems. The estimates of achievable potential contained in this study build on the earlier Power Smart experience and recognize that there are constraints (such as market uncertainties) that cannot be fully addressed by DSM initiatives. However, it is clear that further study of the constraints affecting these potential electricity savings is required.

7. DEMAND IMPACTS

7.1 INTRODUCTION

This section presents an assessment of the demand savings[46] that would occur as a result of the electricity savings contained in each of the three preceding electricity efficiency forecasts, namely:

- Economic Potential
- Most likely Achievable Potential, and
- Upper Achievable Potential.

In each case, both electricity and demand savings are defined relative to the Reference Case presented previously in Section 3. It should be emphasized that the CPR is not a demand reduction study, per se. Rather, the focus is on the Demand Impacts of the electricity efficiency measures contained in the Economic and Achievable Potential forecasts. It is recognized that there are numerous other technologies and control strategies that can be used to reduce peak demand requirements. These technologies and strategies however, are beyond the scope of this study. It is likely that further studies on reducing peak demand requirements will be pursued by BC Hydro in the future.

The discussion in this section is organized as follows:

- Overview of BC Hydro System Load Profiles
- Definition of BC Hydro Annual Demand Periods
- Approach Used to Derive Demand Impacts
- Results.

7.2 OVERVIEW OF BC HYDRO SYSTEM LOAD PROFILES

Exhibit 7.1 shows BC Hydro's load profiles, at the level of both total system and individual sector, for an average winter weekday. The winter period of December and January is when BC Hydro usually experiences its highest levels of electricity demand and, therefore, is the primary focus of this study. As illustrated in Exhibit 7.1, total system peak demand is approximately 8,000 MW[47,48] on an average winter day. It can also be seen in Exhibit 7.1 that the weekday load increases during the 16-hour period from 6 a.m. to 10 p.m.

The industrial sector, which is the focus of this section, is split into two categories, as shown in Exhibit 7.1: industrial customers served at the distribution voltage and industrial customers

[46] As noted previously in Section 1, BC Hydro's previous efficiency efforts had focused on electrical energy savings, since there had not been major capacity constraints on BC Hydro's system. However, capacity constraints are becoming more important to the corporation's operations and planning.

[47] The load profiles presented in this section were derived to be representative of typical daily winter loads within the different regions and sectors of BC Hydro's service area and include line losses. At this disaggregated level data have been approximated using a sample of metered sites that are assumed to characterize the sectors involved. Actual metered data are not available at this level. These load profiles are intended for use only in the context of this study.

[48] BC Hydro's winter system peak is close to 9,000 MW; 8,000 MW is intended to represent a "typical" winter day.

served at transmission voltages. The industrial distribution customers account for about 600 MW of the peak and industrial transmission customers account for 2,000 MW of the peak. Both categories represent about 2,600 MW, or 33% of the total system load on a typical winter weekday.

An Industrial Distribution Customer is one who takes service from BC Hydro at 25,000 volts or less, while a Transmission Industrial customer is one who takes service at Transmission voltages that are 60,000 volts or higher.

Exhibit 7.1: Average Winter Weekday Load Profile—Total BC Hydro System

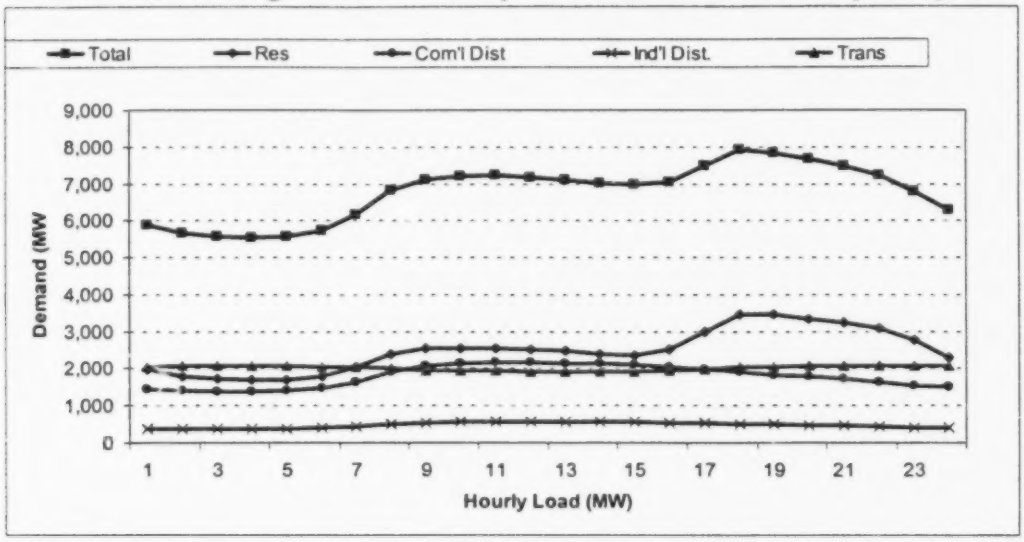


Exhibit 7.2 shows that the shape of the daily industrial load profiles (Distribution) is similar in each of the three service regions, with the Lower Mainland accounting for almost 50% of the total.

Exhibit 7.2: Average Winter Weekday Load Profile—Industrial Sector—Distribution

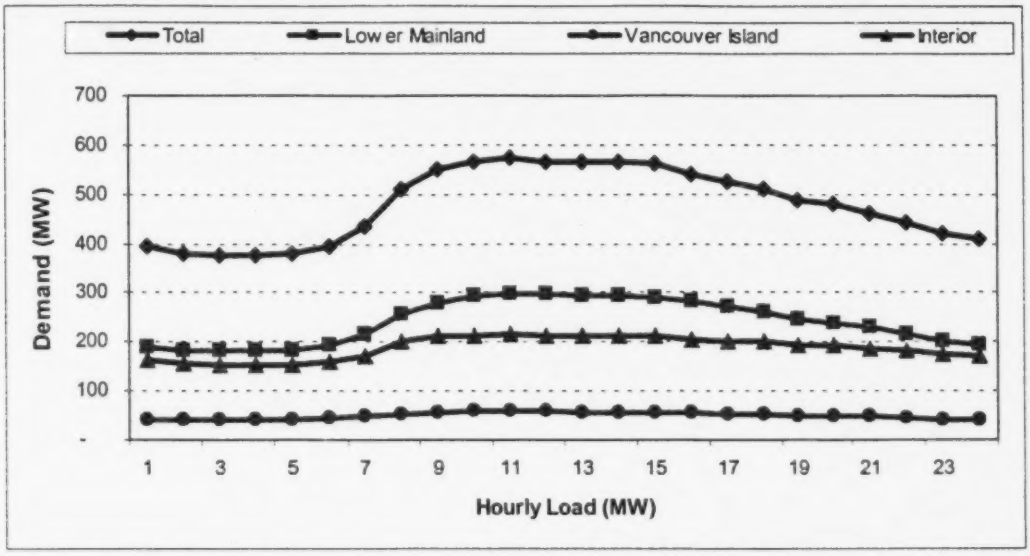


Exhibit 7.3 shows that the shape of the daily industrial load profiles (Transmission) is similar in each of the three service regions, with the Interior accounting for almost 50% of the total.

Exhibit 7.3: Average Winter Weekday Load Profile—Industrial Sector—Transmission

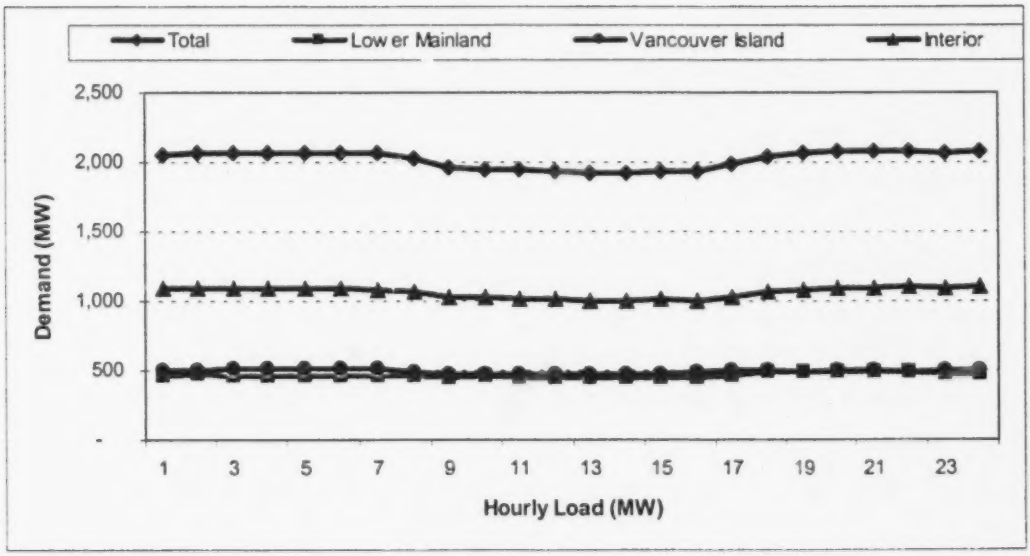


Exhibit 7.4 shows that the ratio of "average" 16-hour weekday demand to "maximum" demand is approximately 94% for the total industrial load on the system. This ratio is moderately higher in the Interior service region than in the other service regions.

Exhibit 7.4: Comparison of "16-Hour Average" and "Peak" Demand (MW) for the Industrial Sector

Average Winter Weekday	Total BCH System	Lower Mainland	Vancouver Island	Interior
Maximum Peak Demand—Industrial Sector (MW)	2,689	790	576	1,323
% of Total (approximate)	100%	30%	21%	49%
Av. 16-hr. Demand—Weekday 6 a.m. to 10 p.m. (MW)	2,515	733	539	1,243
Ratio: Average 16-hr. demand/Max. peak demand (%)	93.5%	92.8%	93.6%	94.0%

7.3 DEFINITON OF BC HYDRO ANNUAL DEMAND PERIODS

Three demand periods were defined for this CPR. They are shown in Exhibit 7.5. As illustrated, the on-peak period selected for this CPR is weekdays from 6 a.m. to 10 p.m. during the months of December and January (referred to as the Winter, On-peak). Weekends and the hours from 10 p.m. to 6 a.m. during the months of December and January are off-peak (referred to as the Winter, Off-peak). The remaining hours of the year are considered to also be off-peak and are referred to as the Shoulder period. The same demand period definitions are used in each of the three service regions: Lower Mainland, Vancouver Island and the Interior.

Exhibit 7.5: BC Hydro Annual Demand Periods—CPR 2002

Period	Months	Days	Hours	Annual Total	
				Hours	%
Winter, On-peak	December 1 to January 31	Monday to Friday, inclusive	6 a.m. to 10 p.m.	709	8.1
Winter, Off-peak	December 1 to January 31	Monday to Friday	10 p.m. to 6 a.m.	779	8.9
		Saturday, Sunday	All hours		
Shoulder	February 1 to November 30	All days	All hours	7,272	83
Total				**8,760**	**100**

7.4 DERIVATION OF DEMAND IMPACTS

The CPR analysis to date has been focused exclusively on potential electricity energy savings. The following discussion outlines the methodology employed to derive demand impacts from the electricity values.

The steps used to derive the demand impacts from the electricity consumption values contained in the three Potential estimates are listed below and discussed in the following paragraphs:

- Annual electricity use in the base year was distributed among the three demand periods, by subsector and end use.
- Using the above data, average winter on-peak demand was calculated for the base year and compared with available utility data.

- The base year electricity use distributions were applied to each of the Reference Case milestones to derive average winter on-peak demand estimates for each period.
- The above process was repeated for the Economic Potential Forecast and average winter on-peak demand estimates for each period in the Economic Potential Forecast were derived.
- Average winter on-peak demand savings were calculated as the difference between the Economic Potential and Reference Forecasts.
- The subsector and end-use specific on-peak energy to demand ratios calculated for the Economic Potential forecast were applied to the savings contained in the Achievable Potential scenarios.

Further discussion of each step is provided below.

7.4.1 Distribute Annual Base Year Electricity Use

The first set of columns shown in Exhibit 7.6 provide a sample distribution of annual electricity use among the three BC Hydro demand periods for the pulp and paper sub sector.[49]

Two tasks are required to generate the data shown in Exhibit 7.6 as follows:

- Distribute annual end-use electricity consumption between the December–January period and the remaining 10 months of the year.
- Allocate the December–January electricity consumption between the winter on- and off-peak periods.

7.4.2 Calculate Base Year Average On-peak Demand

Once the preceding steps were completed the total amount of electricity consumption in the winter on-peak period was calculated. Given that the total number of hours for the on-peak period is also known (i.e., 709 hours), it is possible to calculate the average demand for each end use during the on-peak period using the formula below.

$$\textit{Average end-use "on-peak" demand} = \frac{\textit{Total end-use electricity use * on-peak \%} \times (1 + \textit{line losses})}{\textit{Hours in "on-peak" period}}$$

The above calculation was repeated for each combination of subsector and end use and aggregated to obtain a total industrial demand. Because the calculation begins with actual electricity use in the period, diversity is accounted for. Similarly, as the electricity savings are calculated at the customer level, line losses need to also be added in. For the transmission level-customers, line losses of 3% were used. For the "Other Industry" subsector[50], line losses of 7% were used (3% transmission losses and 4% distribution losses)[51].

[49] Although the load profile for this subsector is generally quite flat, winter consumption is slightly higher because colder temperatures increase the energy required to process the colder raw wood product.

[50] This industrial subsector consists primarily of distribution-level customers.

[51] This approach omits bulk transmission losses of 5%; however, this is consistent with the approach being applied to other possible electricity options, such as small-scale renewable electricity. It is also consistent with the general

Exhibit 7.6: Sample Calculation of Average On-peak Demand for the Pulp and Paper Subsector, (MW)*

End Use	Annual Electricity Distribution (%)				Annual Electricity Use (GWh/yr.) - Ref. Case			Ave On-peak Demand (MW)*		
	Winter On Peak	Winter Off-Peak	Shoulder	Total (check)	2005/06	2010/11	2015/16	2005/06	2010/11	2015/16
Pulp&Paper										
Pumping Systems	9%	9%	82%	100%	3,951	3,221	3,049	517	421	399
Air Displacement	9%	9%	82%	100%	1,603	1,272	1,172	210	166	153
Compression	9%	9%	82%	100%	160	145	138	21	19	18
Conveyance	9%	9%	82%	100%	847	712	658	111	93	86
Process Equipment	9%	9%	82%	100%	5,417	5,184	4,797	708	678	627
Electrolysis	9%	9%	82%	100%	0	0	0	0	0	0
Process Heat	9%	9%	82%	100%	0	0	0	0	0	0
Light	6%	9%	84%	100%	28	33	33	3	3	3
Other	9%	9%	82%	100%	152	181	183	20	24	24
Self Gen	9%	8%	83%	100%	-3,689	-3,238	-3,219	-482	-423	-421
Subsector Total					8,469	7,510	6,811	1,106	981	889

"On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.
* Includes line losses of 3% for transmission-level customers and 7% for distribution-level customers.

The calculated results for the base year were compared with BC Hydro's estimated data; the calculated results were within 1% of the BC Hydro values. As the BC Hydro values shown earlier in this section were intended to be "indicative" for a "typical" day rather than a direct calibration with the CPR data, the results were considered to be in good agreement and no further reconciliation was carried out.

7.4.3 Calculate Average On-peak Demand for Remaining Reference Forecast Years

The same electricity end-use distribution percentages employed in the base year were then applied to each of the milestone periods in the Reference Case. The results are shown in subsection 7.5. Additional detail is also provided in Appendix E.

7.4.4 Calculate Average On-peak Demand for Economic Potential Forecast

Average winter on-peak demand for the Economic Potential Forecast was calculated exactly as outlined above for the Reference Case. As none of the efficiency measures shifted the timing of operations, the end-use distributions of annual electricity consumption remained the same as in the Reference Case.

7.4.5 Calculate Average On-peak Demand Savings for Economic Potential Forecast

Average winter on-peak demand savings were calculated as the difference between the Economic Potential and Reference Forecasts. A sample set of results is shown below in Exhibit 7.7. Additional results are shown in subsection 7.5.

assumption that the most likely future electricity supply options will occur at the regional levels rather that at remote sites, such as the historical large-scale hydroelectric developments.

Exhibit 7.7: Sample of On-peak Demand Reduction for the Pulp and Paper Subsector (Economic Potential), by End Use and Milestone Year, (MW)*

End Use	On-peak Demand Reduction (MW)* (*Relative to Reference Case*)		
	2005/06	2010/11	2015/16
Pumping Systems	105	209	214
Air Displacement	9	9	17
Compression	3	6	6
Conveyance	4	12	17
Process Equipment	87	135	175
Electrolysis	0	0	0
Process Heat	0	0	0
Light	0	0	0
Other	51	53	64
Self Gen	0	0	0
Subsector Total	**259**	**424**	**493**

"On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.
* Includes line losses of 3% for transmission-level customers and 7% for distribution-level customers.

7.4.6 Calculate Average On-peak Demand Savings for Achievable Potential Scenarios

The same electricity end use distribution percentages employed in the Economic Potential Forecast were applied to the electricity savings in the Achievable Potential scenarios.

7.5 RESULTS

This section presents the estimated on-peak demand savings in two exhibits:

- Exhibit 7.8 compares the average on-peak demand estimates for the Reference Case and the Economic Potential and Achievable Potential Forecasts, including the demand savings. The results are presented for each milestone year.

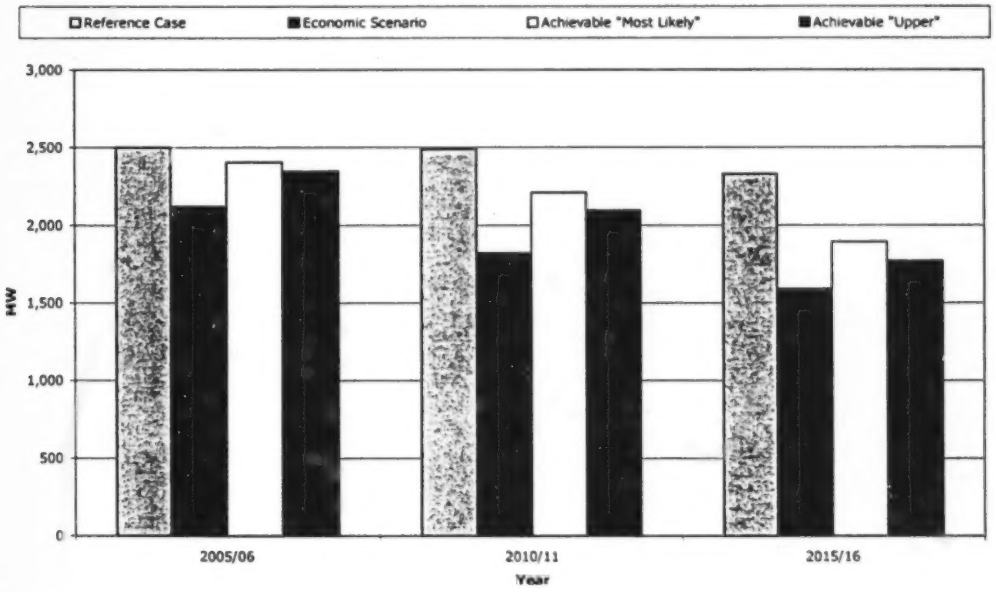
- Exhibit 7.9 is a graph of average "on-peak" industrial sector demand under each scenario.

Exhibit 7.8: Industrial On-peak Demand Savings for Total BC Hydro Service Area, by Scenario and Milestone Year,[52] (MW)*

Average On-peak Demand (MW)*						Potential On-peak Demand Savings (MW)*		
Milestone Year	Base Year	Reference Case	Economic	Achievable		Economic	Achievable	
				Most Likely	*Upper*		*Most Likely*	*Upper*
2000/01	2,542	2,542						
2005/06		2,503	2,123	2,406	2,349	380	97	154
2010/11		2,488	1,823	2,211	2,095	666	277	394
2015/16		2,331	1,591	1,895	1,771	739	436	559

"On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.
* Includes line losses of 3% for transmission-level customers and 7% for distribution-level customers.

Exhibit 7.9: Summary of Average Industrial On-peak* Demand for Total BC Hydro Service Area, by Scenario and Milestone Year, (MW)



* "On-peak" is weekdays from 6 a.m. to 10 p.m. during the months of December and January.

[52] Further regional breakdown of data is not provided for the industrial sector to ensure customer confidentiality.

8. ADDITIONAL TECHNOLOGIES

8.1 INTRODUCTION

In the introductory section to this report, Exhibit 1.1 presented the full range of technologies that were identified by the study team for consideration. The introduction also noted that technologies shown in Exhibit 1.1 were organized into two groups:

- ***Electrical-efficient technologies that are commercially available today, or will be available by 2005.*** These technologies are the primary focus of this study.

- ***Electrical-efficient technologies that are not commercially available today but are expected to become available after 2005 but before the end of the study period.*** These emerging technologies have not yet been included in this study. They are addressed in a qualitative manner in this section.

In addition, the introductory section also noted that there are numerous other technologies that could contribute to B.C.'s electricity future but are not included in this study as they are outside the agreed scope. For example, the use of pulp storage in a pulp mill or demand controllers in any industrial facility provide opportunities to reduce peak demand; however, consideration of such specific load control technologies was outside the scope of this study. Similarly, technologies involving the use of natural gas fired engines to drive air compressors or large pumps can also result in reduced electricity use. However, they also are not included, because they represent alternate energy sources. The exclusion of both groups of technologies does not imply any judgment on their potential contribution—only that the limits of time and resources required that this study focus on those technologies that are commercially available today, or will be available by 2005.[53]

Based on client discussions held in the early stages of the study, the following emerging technologies were selected for review:

- Two-photon lamp
- Advanced refrigeration technologies
  - Carbon dioxide refrigeration
  - Magnetic refrigeration
  - Thermo-acoustic refrigeration
  - Linear compressors
- Advanced electric motors
- Advanced mechanical pulping technologies
- Advanced chemical pulping technologies
- Advanced drying technologies
- Advanced wastewater treatment technologies.

The remainder of this section provides a brief discussion of the above technologies. In each case the discussion provides a brief description of the technology, including: its current development

[53] It is also recognized that additional technologies, not currently envisioned, may emerge over the study period that will provide further opportunities for electrical efficiency.

status and forecast dates for commercial introduction; an estimate of its electricity efficiency improvements over conventional technology; and, an estimate of its potential CPR impacts (e.g., how significant are the potential additional electricity savings?)

8.2 TWO-PHOTON LAMP

Fluorescent lighting systems employing lamps with two-photon phosphors (two visible per one ultraviolet) have been discussed as a concept for more than a decade; however, the U.S. DOE has now included them in their most recent lighting "Technology Roadmap" as an intermediate target technology. If this target date were met, then early commercial availability would be expected in the next 5 to 10 years. This technology, which consists of new phosphor materials, electrode materials and ballast designs, promises to increase lighting efficacy levels into the range of 180 to 230 lumens/watt, which is about twice the levels currently available.

8.2.1 Impact of Two-photon Lamp

The impact of this emerging technology would be modest given that lighting represents about 2% of the total industrial electricity used in the base year, or about 490 GWh/yr.

8.3 ADVANCED REFRIGERATION TECHNOLOGIES

This category includes the following four emerging refrigeration technologies:

- Carbon dioxide refrigeration
- Magnetic refrigeration
- Thermo-acoustic refrigeration
- Linear compressors.

8.3.1 Carbon Dioxide Refrigeration

The trend towards elimination of chlorine-based refrigerants has renewed interest in carbon dioxide as a refrigerant. Although the use of CO_2 appears contrary to current climate change concerns, the quantity of CO_2 that would actually be used in a refrigeration system is trivial compared to the amounts produced by burning fossil fuels.

A recent large demonstration project in a major food manufacturing plant in the United Kingdom confirmed the viability of using a CO_2/ammonia-hybrid refrigeration system. The demonstration refrigeration project reduced energy consumption, reduced risks of releasing a toxic substance, and assisted in the elimination of chlorine-based substances. Further data on subsequent developments are pending at this time.

8.3.2 Magnetic Refrigeration

Compounds of gadolinium, silicon and germanium have been found to heat up when magnetized and cool down when removed from a magnetic field. This effect can be large enough to produce a practical cooling effect. Magnetic refrigeration has the potential to

produce higher efficiencies than conventional vapour-compression cycles without the use of harmful HFCs or CFCs. There are many potential uses for this new technology, but the most promising uses are for refrigeration/freezing and air conditioning. It may also eventually be used in the production of inexpensive liquid hydrogen as a future fuel source.

Magnetic refrigeration is currently still in the prototype stage with research being conducted by the Ames laboratory and the Astronautics Technology Center. The first prototype achieved a cooling power of 600 watts with an impressive coefficient of performance (COP) of 15 using a powerful superconducting magnet. Initial design studies indicate that household magnetic fridge/freezers (which would use less powerful magnets) could have a COP of 3 with a total cooling of 120 watts. Magnetic refrigeration is about 20% more energy efficient than traditional cooling systems. Although initial costs will be greater than conventional systems, simple payback periods are expected to be in the range of 5 years[54].

It will take from 5 to 10 years to move magnetic refrigeration to the marketplace, where it will likely find its early niche in large supermarket chains, shopping malls, food storage warehouses and possibly industrial refrigeration applications.

8.3.3 Thermo-acoustic Refrigeration

Thermo-acoustic refrigeration employs acoustic power to pump heat. An acoustic driver generates a standing wave that creates a linear temperature gradient within densely packed parallel plates. This temperature gradient is caused by an irreversible heat transfer between the working fluid, which is a noble gas, and the stack plates. The simplicity of thermo-acoustic devices could lead to refrigerators and cooling systems with low manufacturing and maintenance costs and new kinds of air-conditioning systems.

Prototypes have been made, but more research is needed to improve the performance of the heat exchangers used in the system. Research is currently underway at Johns Hopkins University and Purdue University.

Performance calculations for thermo-acoustic refrigerators predict that future coefficients of performance (COPs) will be about 40% to 50% of the ideal Carnot cycle. This is about twice the maximum COPs achieved to date. One reason for the gap between the theory and practical devices is the poor performance of the heat exchangers[55].

8.3.4 Linear Compressors

A linear motor/compressor can replace the standard rotating motor/compressor as the prime mover in a conventional Rankine cycle refrigerator. It is compatible with CFC or non-CFC working fluids, requires no lubricant and maintains a higher electric efficiency than any existing rotating motor/compressor commercially available today.

[54] ASHRAE Journal, Industry News, *Magnetic Refrigeration*, January 2002.
[55] www.me.jhu.edu/~htl/research/thermoacoustic/thermoacoustic.htm

LG Electronics from Korea recently announced that it had successfully tested a linear compressor in a 24-cu. ft. commercial refrigerator at the 2000 Appliance Manufacturer Conference and Expo. As with the previous refrigeration technologies, this emerging technology has so far focused on small residential-type prototypes. However, the technology could be extended to larger equipment used in industrial refrigeration applications.

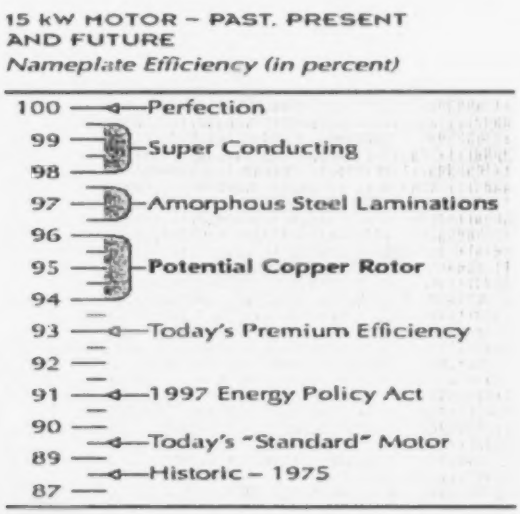
8.3.5 Potential CPR Impacts of Advanced Refrigeration Technologies

The impact of the above refrigeration technologies would be modest given that industrial refrigeration represents less than 2% of total industrial electricity consumption.

8.4 ADVANCED ELECTRIC MOTORS

The core analysis for this study addressed Premium Efficiency Motors.[56] However, further efficiency improvements are under development, as shown in Exhibit 8.1, below.

Exhibit 8.1: Potential Motor Efficiency Improvements



Source: Darryl Van Son, Motor Test Results presented at Die Cast Copper Motor Rotor Workshop and Technology Demonstration Meeting, January 29, 2002, Denver, CO.

A brief description is provided for the following motor technologies:

- Copper rotor
- Amorphous steel laminations
- Superconducting.

[56] The Premium Efficiency Standard was announced in May 2001 by the Motor Generator Section of the National Electrical Manufacturers Association (NEMA).

❑ **Copper Rotor Motors**

Copper rotor motors, which may be able to obtain a further 1 to 3 % efficiency improvement over today's Premium Efficiency Motors, could be the next step in motor efficiency development. However, there are still some major technical hurdles to overcome before these motors will be commercially available. A recent report[57] by the Copper Development Association notes that, to win acceptance by motor manufacturers, the manufacture of copper rotors needs to be compatible with current production equipment. To meet that requirement, the copper industry needs to find a way to deal with the production challenges posed by the thermal differences between molten copper and conventional technology, which currently have a negative effect on die life.

❑ **Amorphous Steel Laminations**

Motors utilizing amorphous steel laminations could lead to a further 2% improvement over copper rotor motors. Amorphous magnetic materials have been widely used for simple applications (non-geometric) such as transformers and flat-wound devices. Until recently, this technology had not been applied to motors due to a number of technical obstacles related to the gathering, bonding, annealing and cutting of these materials for use in making motor parts. An Australian company, AMM Technologies, claims to have overcome these obstacles and has used the amorphous magnetic materials to produce motor prototypes. The technology remains at the early demonstration stage.

❑ **Superconducting**

The highest theoretical potential increase in motor efficiency would occur in motors that are manufactured with superconducting material. At the present time, superconducting materials only have their superconducting characteristic at extremely low temperatures. It is not currently anticipated that this issue will be technically resolved within this study's time frame.

8.4.1 Impact on CPR of Advanced Motor Technologies

The impact of these emerging motor technologies could be significant because electric motors represent about 95% of total industrial electricity use.

8.5 ADVANCED MECHANICAL PULPING TECHNOLOGIES

The following mechanical pulping measures were reviewed:

- On-line pulp analysis
- Biological treatment of wood chips
- Advanced refiners.

[57] Copper Development Association; *Technology Transfer Report—The Die-Cast Copper Motor Rotor; 2002.*

❑ **On-line Pulp Analysis**

A number of different types of real-time, on-line pulp analysis equipment are under development. These technologies improve a mill's ability to determine the physical characteristics of the refined pulp output at different stages in the process and, similarly, to optimise energy requirements at each stage. One example is the use of ultrasonic probes that characterize slurry on-line in vessels and pipelines.

❑ **Biological Treatment of Wood Chips**

Extensive research and development work is underway to assess the advantages of various treatment processes for wood chips prior to their use in mechanical refining processes. Chemical treatment of chips, prior to the refining process, is commonly used to meet different product quality requirements (brightness, opacity, and strength). As the process softens the wood chips, it also results in a significant reduction in pulping energy requirements.

Biopulping International Inc. is developing a treatment process that uses a natural wood-decaying fungus prior to mechanical pulping. The process would augment the existing pulping process and would not involve major refining replacements. First sales of the technology are expected in the near future.

❑ **Advanced Refiners**

New refiner designs make it more practical to recover and utilize steam energy rather than exhaust it to the atmosphere. Heat recovery equipment can also be retrofitted to existing refiners but at much reduced levels of effectiveness. Although some aspects of this technology are contained in the core analysis of this CPR, some additional technologies and measures promise to further increase overall efficiency. These include operating refiners at higher pressures, optimizing steam cycles so that steam recovered can be used to generate electricity and improving the equipment used to clean the exhausted steam.

8.5.1 Impact of Advanced Mechanical Pulping Technologies

B.C.'s industrial sector uses a large amount of electricity to produce pulp, particularly pulp produced by mechanical processes. In rough terms, the advanced technologies noted above could further reduce annual electricity consumption by 20 to 30%, or by about 400 to 500 GWh/yr.

Due to the cost of electricity in the production of mechanical pulp, customers are highly motivated to pursue energy saving initiatives with respect to this process. In general, energy improvement modifications are capital intensive and industrial customers often have difficulty raising the necessary capital.

8.6 ADVANCED CHEMICAL PULPING TECHNOLOGIES

The following chemical pulping measures were reviewed:

- Black liquor gasification
- Medium-consistency pumping.

❑ Black Liquor Gasification

Black liquor gasification offers pulp and paper mills the most efficient method for converting biomass energy to electric power, with thermal efficiencies of 74% compared to 64% in modern recovery boilers. A Georgia-Pacific mill in the U.S. plans to implement a pilot project in the near future. This project involves utilizing a reactor in which tubes, heated by pulses of fired gas, are immersed in a mixture of sodium carbonate and spent black liquor. The pulsing enhances a heat exchange between the tubes and the mixture promotes chemical reactions that produce the fuel that is used to produce steam.

❑ Medium-consistency Pumping

The Kraft process uses a large amount of electricity for pumping. Traditionally, the transporting of pulp from thick-stock storage involves first diluting the slurry prior to pumping and then re-thickening for the next process stage. These transport systems, which include auxiliary filtrate tanks, dilution pumps and controls, are both capital and energy intensive. Medium-consistency pumps and mixers have been developed that enable the transport of thick-stock, which eliminates the need for dilution and subsequent thickening. Industry has already applied this technology in some process areas such as the bleach processing. However, medium-consistency washing and screening require considerable further development. This technology will also reduce the volume of water required, which will reduce water cleanup costs. At this time, it is not certain how much electricity reduction would occur from a more extensive application of this technology.

8.6.1 Impact of Chemical Pulping Improvements

Due to the forecast decline in chemical pulp production, the preceding technologies are not expected to have a significant impact on the CPR results over the study period.

8.7 ADVANCED DRYING TECHNOLOGIES

A substantial amount of energy is used to dry paper and dry lumber. Although most of the heat is provided by natural gas or steam, a significant amount of electricity is used for fans that circulate hot air or exhaust steam.

Two additional emerging drying technologies were reviewed:

- Control technologies
- Drying electro-technologies.

❑ **Control Technologies**

In lumber drying, the objective is to dry each piece of lumber to a specific moisture level (usually its equilibrium moisture level). The actual level depends on the species involved (often in the 12% moisture level). If pieces are over-dried they may crack or warp, degrading the lumber. If they are under-dried, the lumber is more likely to deform in its end use due to the drying that will take place over time.

Advanced control technologies for drying lumber improve product quality, increase productivity and reduce energy use. Acoustic humidity sensors are one promising example of enhanced drying control technologies. Currently, a demonstration project is building and testing a prototype acoustic humidity sensor that will be integrated into a humidity control system that measures and corrects the humidity in a paper dryer. This technology sends a sound pulse through the air in the paper dryer and compares it to a sound pulsed through a closed dry-air tube at the same temperature. By allowing the dryer to operate at the lowest temperature possible, the sensor can greatly reduce energy consumption while avoiding condensation problems that are caused when the temperature is too low.

❑ **Drying Electro-technologies**

A number of drying electro-technologies are under development. One promising example, which is currently being developed by the B.C. company HeatWave Technologies Inc. involves the use of radio frequency (RF) generating technology. The company claims that its electro-magnetic system is able to penetrate and heat entire volumes of lumber uniformly and quickly. This is in contrast to conventional drying technology that requires heat energy to be conducted from the outside of the material into the centre, which requires long processing times and high-energy inputs.

This technology would involve switching from fossil fuel, currently used to provide the dryer heat energy, to electricity. As fuel switching is outside the scope of this study, electro-technologies such as radio frequency drying have not been considered.

8.7.1 Impact of Advanced Drying Technologies

Significant improvements in the drying electro-technologies would, of course, increase electricity consumption with respect to electricity used in lumber drying. With respect to improved control technologies, the reduction would be achieved in the fan energy used within the wood sector. It is not anticipated that this technology would significantly increase the energy saving potential already identified in the core CPR study.

8.8 ADVANCED WASTEWATER TREATMENT TECHNOLOGIES

The following wastewater treatment technologies were reviewed:

- Enhanced aeration
- Electrodeionization.

- **Enhanced Aeration**

By applying mechanical forces, such as cavitation, to reduce the median flocculation size, the aeration process used in wastewater treatment can be enhanced. One technology, which is currently being developed under the name Bio-Lysis,[58] involves a specially designed spinning rotor inside a stationary stator, which disrupts the microbial cell membranes in wastewater sludge. This process has demonstrated that it effectively reduces the size of the microbial waste, thereby reducing sludge aeration requirements by 10%.

- **Electrodeionization**

Electrodeionization, also called "electrochemical ion-exchange", is a technology that blends the features of ion-exchange (an adsorption technology) and electro dialysis (a membrane-separation technology). Development work on this technology is continuing in an effort to make it commercially ready for large-scale operations. The advantages of electrodeionization over the single technologies include greater energy efficiency, elimination of chemical regenerants (acids and bases) and elimination of salty wastewater streams. The Argonne National Laboratory is currently conducting laboratory studies of this technology.

8.8.1 Impact of Advanced Wastewater Treatment Technologies

The demand for wastewater treatment by industry and municipalities is expected to increase in the future in response to growing water quality concerns. The application of these advanced technologies will reduce pumping horsepower requirements.

[58] This technology is currently supported by the National Industrial Competitiveness through Energy, Environment, and Economics (NICE[3]).

9. SUMMARY OF FINDINGS

The study findings confirm the existence of significant potential cost-effective electricity savings in B.C.'s industrial sector. In the most likely and upper achievable scenarios, those electrical efficiency improvements would provide between 3,374 and 4,338 GWh/yr., respectively, of electricity savings by FY 2015/16, as well as on-peak demand savings of approximately 436 to 559 MW.

The three areas offering the most significant electricity saving opportunities are mechanical pulping enhancements, pump system improvements and steam cycle optimization (i.e., greater use of steam turbines to generate electricity at mill sites). These three areas account for 74% of the most likely achievable savings and all involve the pulp and paper sector. It is important to note that realizing these potential savings would require a significant amount of specialist engineering work and a significant level of capital investment. The study notes that the current market conditions provide a unique opportunity to significantly reduce the amount of electricity used by this sector with the added benefit of improving its efficiency and competitiveness.

Note: As in any study of this type, the results presented in this report are based on a number of important assumptions. Assumptions that are particularly influential include:

- **Future production levels and product mix.** The study employs BC Hydro's forecast of future production levels and product mix for B.C.'s industrial sector. However, changes in either factor can significantly affect future electricity requirements and, consequently, the results contained in this analysis.

- **The current penetration of energy efficient technologies and the actual operating efficiency of the equipment that is in place today.** To determine the operating efficiency of all of the pumping systems within even one large pulp and paper mill would literally take millions of dollars, which is far beyond the scope of this study. Accordingly, the study relies on information accumulated over a number of years by the consultants performing this study as well as existing data within the ISTUM model.

- **The cost of implementing energy saving measures.** For large energy saving projects, such as a steam optimization project, detailed (and expensive) engineering studies are required at each identified site. Such studies are well beyond the scope of this study. Therefore, the information used in this study has been drawn from a few recent studies and the results of those studies have been extrapolated to the remaining identified projects.

- **The rate at which new technologies or processes are developed and implemented.** Emerging technologies were identified in Section 8, together with a broad estimate of their potential impact on future electricity consumption. However, it is not possible to fully anticipate all of the possible new technologies that may achieve commercial viability over the study period. For example, if improved price signals are provided that more fully reflect actual costs, then it is possible that the rate of new technology development and deployment into the market place may increase beyond the levels assumed in this study.

One recommendation emerging from this study is that BC Hydro consider implementing focused studies of energy-intensive end-uses, such as mineral ore grinding, pulp refining and electro-chemical production. The objective would be the establishment of aggressive energy saving targets. Such studies could be a collaborative effort between BC Hydro and customer groups with the objective of improving the competitiveness of participating B.C. industry sectors.

- **Potential contribution of behavioural changes**. Consistent with the study's scope, this analysis has focused on "hard-wired" options involving improved efficient equipment and processes. One of the reasons for this focus is that it is easier to monitor and measure the impact of these types of changes and it is more likely that the savings will be permanent. However, behavioural changes can add further savings and can be permanent if customers are exposed to the full cost of electricity at the margin on a continuous basis. Additional effort is required to understand the potential contribution of behavioural change in the industrial sector. This area could be particularly significant if a two-step electricity rate is introduced as proposed by the provincial government's 2002 Energy Plan.

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11. GLOSSARY OF TERMS

(NOTE: underlined expressions are defined in this glossary.)

achievable potential:
The portion of savings identified in the economic potential that could realistically be achieved within the study period.

avoided cost:
The unit cost of acquiring the next resource to meet demand, which is used as a measure for evaluating individual demand- and supply-side options.

BC Hydro service area:
The portion of the Province of B.C. that receives retail electricity service from BC Hydro. The service region excludes the area served by Aquila Networks Canada (previously known as West Kootenay Power and Utilicorp Networks Canada) and, for the purpose of this study, includes the city of New Westminster. Approximately 75% to 80% of B.C.'s demand for electricity is in the BC Hydro service region and is supplied by BC Hydro.

co-generation:
The simultaneous production of electric or mechanical energy and useful heat energy from a single fuel source; for example, several mills in the B.C. forest sector co-generate electricity and process steam from wood waste for use in a pulping process.

cost of conserved energy (CCE):
The annualized unit energy cost of a DSM measure used to determine its cost effectiveness compared to additional electricity supply (as part of the Total Resource Cost Test). It is calculated as the annualized incremental cost (including annual O&M) of the DSM upgrade measure divided by the annual energy savings achieved, excluding any administrative or program costs to achieve full use of the technology or measure.

demand impacts:
In the context of the Conservation Potential Review 2002, this term refers to the average load reduction over the 6 a.m. to 10 p.m. period during an average weekday in December and January that is anticipated to result from the various electricity saving technologies, programs or actions presented in the CPR 2002.

demand-side management (DSM):
Actions that modify customer demand for electricity and that can defer the need for new energy and capacity additions.

diversity
A relative measure of the likelihood that a series of connected loads will reach peak demand at the same time. A **high diversity** implies that individual connected loads will reach their peak demand at different times whereas a **low diversity** implies that they will reach peak demand at the same time.

economic efficiency:
Allocation of human and natural resources in a way that results in the greatest net economic benefit, regardless of how benefits and costs are distributed within society.

economic potential:
An estimate of the reduction of electricity consumption, relative to the reference case, that would occur if all electricity-consuming equipment were upgraded to the efficiency level that is cost-effective as calculated using the cost of conserved energy (CCE).

electric capacity:
The maximum electric power that a device or system is capable of producing or transferring. Electric capacity is measured in watts, kilowatts, megawatts etc.

electric energy:
It is the cumulative amount of electricity produced or consumed over a period of time. Electric energy is measured in kilowatt hours or gigawatt hours.

electric power:
The instantaneous rate that electric energy is produced, transmitted or consumed. Electric power is measured in watts, kilowatts, megawatts, etc.

electrical efficiency:
The ratio of the useful energy delivered by a system or end-use to the amount of electric energy supplied to it. This ratio measures how well electric energy is translated into another useful form of energy.

electrical intensity:
The ratio of electric energy consumed per application or end-use; for example, kilowatt hours per square metre of lit office space per day or kilowatt hours per tonne of aluminum produced. All else being equal, electrical intensity increases as electrical efficiency decreases.

electricity conservation:
Activities by electricity users that result in a reduction of the electric energy used to provide electric energy services. Electricity conservation can include a wide variety of behavioural or operational changes that result in energy savings. For the purpose of this study only, energy savings achieved through hard-wired or hardware installations are included.

emerging technologies:
New energy-conserving technologies that are expected to be market-ready after 2005 and up to and including 2015. This category includes technologies that could be accelerated into the market during that period through targeted financial or technical support.

end-use:
Recognition of the fact that electric energy is of no value to a user without first being transformed, by a piece of equipment, into a service of economic value. For example, office lighting is an end-use, whereas electricity sold to the office tenant is of no value without the

equipment (light fixtures, wiring, etc.) needed to convert the electricity into visible light. End-use is often used interchangeably with energy service.

energy service:
An amenity or service supplied jointly by energy and other components/equipment such as buildings, motors and lights. Examples of energy services include residential space heating, commercial refrigeration, aluminum smelting and public transit. The same energy service can frequently be supplied with different mixes of equipment and energy.

financial incentive:
Certain financial features in the utility's demand-side management programs designed to motivate customer participation. They may include features designed to reduce a customer's net cash outlay, pay-back period or cost of finance to participate.

fuel substitution:
The ability to use a different fuel to produce the same energy service; for example, natural gas can be used for space heating instead of electricity.

gigawatt hour (GWh):
One million kilowatt hours.

independent power producer (IPP):
A privately owned electricity-generating facility that is usually connected to a utility's transmission system to sell electricity.

kilowatt (kW):
One thousand watts; a basic unit of measurement of electric power. The amount of energy transferred at a rate of one kilowatt for one hour is a kilowatt hour.

kilowatt hour (kWh):
The basic unit of measurement of electric energy, one kilowatt hour, represents the power of one thousand watts for a period of one hour. A typical non-electrically heated home in B.C. uses about 10,000 kWh per year.

load:
The amount of electricity required by a device, customer or group of customers as measured by an electricity meter. Load may be measured instantaneously in terms of electric capacity in units such as kilowatts. Over time load may be measured in terms of energy in units such as kilowatt hours.

load displacement:
The reduction of electricity requirements from existing utility customers through electricity conservation or through customer self-generation.

load factor:
The ratio of the average load supplied during a given period to the maximum load occurring during the same period.

load forecast:
An estimate of expected electricity requirements that have to be met by the electrical system in future years.

load shape:
The variation in electrical load over time, usually hour-by-hour. A load shape can be for the system, a customer or an end-use load over a set period such as a day or a year.

load shifting:
Utility DSM program to move electricity consumption from one period to another, most often from periods of high electricity consumption to periods of low electricity consumption (i.e., from on- to off-peak).

megawatt (MW):
One thousand kilowatts.

natural change in electrical intensity:
The future change in electrical intensity that is expected to occur in the absence of utility demand-side management programs. In developing an estimate of natural change in electrical intensity, it is necessary to make an explicit assumption about the future prices of electricity and competing fuels.

peak demand:
The maximum electric power required by a customer, device or system during a specified period (e.g., day, month, year).

peak clipping:
Utility DSM program used to reduce peak demand, without reducing demand at other times of the day or year.

Power Smart:
BC Hydro's demand-side management initiative, originally launched in 1989. Power Smart includes a full range of DSM programs aimed at BC Hydro's residential, commercial and industrial customers.

rate:
Generically refers to a utility's rate structure. **Average rate** specifically refers here to the overall average revenue per kilowatt hour that the utility receives from a given class of customers (e.g. residential) covered by one or more tariffs.

rate structure:
The formulae used by a utility to calculate charges for the use of electricity. For example, the present BC Hydro rate structure for residential customers consists of a basic monthly charge plus charges for the amount of electric energy used (i.e., cents/kWh). Other BC Hydro rate structures charge for energy at a rate per kilowatt hour that depends on the level of consumption, whereas others may include charges for peak demand.

reference case:
An estimate of the expected level of electricity consumption that would occur over the study period in the absence of any new Power Smart initiatives after 2000/01.

resource planning:
The process of long-term planning of electricity generation and transmission facilities to reliably meet the forecast requirements of BC Hydro's domestic customers. It addresses regional supply requirements and can utilize both supply- and demand-side resources while recognizing economic, environmental and social impacts and risks.

Resource Smart:
The name given to BC Hydro's strategy of improvements to existing power generation and transmission facilities to achieve supply-side efficiency through physical and operational modifications.

sector:
A group of customers having a common type of economic activity. BC Hydro divides its customers into three principal sectors: residential, commercial and industrial. Sectors are often divided into subsectors. For example, "offices" is a subsector of the commercial sector.

self-generation:
Generation of electricity by an industry or commercial enterprise whose principal product is not electricity. Self-generation can either reduce the amount of electricity purchased from the utility or it may be sold to the utility as a supply-side resource.

subsectors:
A classification of customers within a sector by common features. Residential subsectors are by type of home (single-family, duplex, apartment, etc.). Commercial subsectors are generally by type of commercial service (office, retail, warehouse, etc.). Industrial subsectors are by product type (pulp and paper, solid wood products, chemicals, etc.).

tariff:
The rate and the terms and conditions of sale for electric power and energy between utility and customer. It includes the type of service, delivery point(s), limitations of obligations to serve, minimum charges, etc.

technical efficiency:
The efficiency of a system, process or device in achieving a certain purpose, measured in terms of the physical inputs required to produce a given output.

total resource cost:
The total economic cost of acquiring energy resources. For DSM programs, this includes costs incurred by the utility (DSM program administration, taxes and incentives) and by the customer (the cost of the DSM measure net of incentives).

utility cost:
The total financial cost incurred by the utility to acquire energy resources. For DSM, the costs include all utility program costs, including incentive costs.

watt:
The basic unit of measurement of electric power.

12. ABBREVIATIONS AND ACRONYMS

AC – Alternate Current

ASD – Adjustable Speed Drive

BI – Backward Inclined

CCE – Cost of Conserved Energy

CCGT – Combined Cycle Gas Turbines

CFC – Chlorofluorocarbon

CFL – Compact Fluorescent Lights

CO_2 – Carbon Dioxide

COP – Coefficient of Performance

CPR – Conservation Potential Review

DC – Direct Current

DOE – Department of Energy

DSM – Demand Side Management

FY – Fiscal Year

GWh – Gigawatt Hours

HFC – Hydrofluorocarbon

HID – High Intensity Discharge

hp. – Horsepower

HVAC – Heating, Ventilation, and Air Conditioning

IPP – Independent Power Producer

ISTUM - Industrial Sector Technology Use Model

IT – Information Technology

kg. – Kilogram

LED – Light Emitting Diode

m^3 – Cubic Meter

MDF – Medium-Density Fibreboard

MG – Motor-Generator

MW – Megawatt

NCCP – National Climate Change Program

NEMA – National Electrical Manufacturer Association

O&M – Operation and Maintenance

OSB – Oriented Strand Board

PLC – Programmable Logic Control

psig. – Pound Per Square Inch At Gauge

RF – Radio Frequency

SS – Solid State

TRC – Total Resource Cost